RECREATIONS

IN

MATHEMATICS

AND

NATURAL PHILOSOPHY.

IN FOUR VOLUMES.

VOL. IV.

RECREATIONS

IN

MATHEMATICS

AND

NATURAL PHILOSOPHY:

CONTAINING

AMUSING DISSERTATIONS AND ENQUIRIES CONCERNING A VARIETY OF SUBJECTS THE MOST REMARKABLE AND PROPER TO EXCITE CURIOSITY AND ATTENTION TO THE WHOLE RANGE OF THE MATHEMATICAL AND PHILOSOPHICAL SCIENCES:

The Whole treated in a pleasing and easy Manner, and adapted to the Comprehension of all who are the least initiated in those Sciences: viz.

ARITHMETIC,	ASTRONOMY,	PNEUMATICS,
GEOMETRY,	GEOGRAPHY.	HYDROSTATICS,
TRIGONOMETRY,	CHRONOLOGY,	HYDRAULICS,
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OPTICS,	NAVIGATION,	ELECTRICITY,
ACOUSTICS,	ARCHITECTURE,	CHEMISTRY,
MUSIC,	PYROTECHNY,	PALINGENESY, &c.

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MATHEMATICAL

AND

PHILOSOPHICAL

RECREATIONS.

PART ELEVENTH.

Containing every thing most curious in philosophy in general, and in its various branches.

HAVING gone through the different parts of the mathematics, and of the sciences or arts comprehended under that head, we now enter the field of philosophy, which presents as many objects worthy of exciting our curiosity as the mathematics; or, rather, which is indeed still more fertile in that respect, and affording matter still better adapted to the comprehension of the generality of readers. This matter is even so abundant, that we can scarcely establish divisions in it; so that this part of our work will be a kind of a miscellany, without much order, of every thing that belongs to philosophy in general. We shall successively review in it, the principal properties of bodies; the inventions, whether useful or amusing, to which these properties have given birth; various questions relating to the system of the world, to meteors, and the origin of springs, with other objects, which it would be too tedious

to enumerate. But before we enter this vast field, it is necessary that we should establish some general principles, which we shall do in the following account of what philosophers have called the four elements, viz, fire, air, water, and earth.

PRELIMINARY DISCOURSE,

On the Elements of Bodies.

In analyzing any material, when we have arrived at its last component parts, and cannot decompose them farther, we ought to regard them as its elements. Now every one knows that all or most bodies, submitted to analysis, furnish a fixed matter; also something that is inflammable; an invisible fluid, which manifests itself only by its expansibility and its resistance; and lastly another which heat raises into vapours, and which afterward reunites under a visible form. These four component parts have been named *earth, fire, air*, and *water*. These enter into the composition of most bodies; but cannot themselves be decomposed. They ought therefore to be considered as the elements of all other bodies; which justifies the common denomination, which has been established almost from the first dawn of philosophy, according to which there are in nature the four elements, fire, air, water, and earth.

§ I. *Of fire, both elementary and material.*

What is fire? This is perhaps one of the most obscure questions in philosophy, and the least susceptible of a satisfactory answer. The most probable account however, which its known properties enable us to give, is the following.

Fire is a fluid universally diffused throughout nature; which penetrates all bodies with more or less facility; is susceptible of being accumulated in some of them, and this accumulation produces, in regard to us, that sensation which we call heat. When this accumulation is carried

to a higher degree, it produces inflammation and combustion, which are always accompanied with light. In every state, this fluid dilates bodies in proportion to the greater or less quantity of it present; and it at length separates their parts, which we call fusing, burning, calcining.

That fire is a fluid, there can be no reason to doubt; for if it were not, how could it be diffused throughout the atmosphere, and throughout water, without forming an obstacle to the motion of bodies? How could it penetrate the densest and most compact bodies, such for example as metals?

Nay, fire is not only a fluid, but it is even the principle of all fluidity; without its influence, all the fluids, with which we are acquainted, would be reduced to masses absolutely solid. Metals become fixed at a degree of heat far superior to that of boiling water. Water loses its fluidity as soon as the heat or quantity of fire has been diminished to a certain degree. Spirit of wine, and even mercury, are congealed by the progressive diminution of heat. There is a degree of cold, or privation of heat, perhaps, which would convert air into a fluid like water, and even into a solid body: but we are at a prodigious distance from that term.

Fire penetrates all bodies with more or less facility.—This follows from the communication of heat from a hot to a cold body. It is with greater or less, a moderate facility, and not with extreme facility, that heat is communicated: for it is well known, that this communication is not instantaneous: if the point of a pretty long needle be presented to the flame of a taper, both its ends do not become equally hot at the same time. One body receives this heat more readily than another; or, as we may say, has a greater affinity for heat.

The accumulation of the igneous fluid produces on our bodies that sensation which we call heat.—This requires no proof; but the sensation is only relative. As long as the

to [illegible] hotter than the body with-
n[illegible]r seems to us cold; but it
c[illegible] warm, if the hand be colder,
[illegible]ous fluid; or if that fluid tends
[illegible] from that body into the hand.
[illegible] acquainted with the following ex-
[illegible]und in a very high degree, and cool
[illegible] the temperature of ice; if you then
[illegible] into tepid water, the one will ex-
[illegible] of cold, and the other of heat.

[illegible]*, carried to a considerable degree, pro-* [illegible]*, always accompanied with light.*—It re- [illegible] experiments made by Buffon, that iron [illegible] without being in contact, to the action of another [illegible] state of inflammation, becomes itself inflamed [illegible] But an ignited body is nothing else than a body [illegible] the igneous fluid is accumulated to such a degree [illegible] luminous. All light indeed is not accompanied with heat; but all heat, carried to a certain degree, produces light.

Has fire weight?—It appears to us that there can be no doubt that fire is heavy: it is matter, since it acts upon matter; and therefore it must possess weight. But the question is, to know whether this weight is perceptible, and can be indicated by the instruments which we employ. s'Gravesande and Muschenbroeck made some experiments on this subject; but they found no difference between masses of ignited iron, or iron penetrated with fire, and the same masses when cold. They however concluded from them, that as ignited iron, which by its increasing in volume ought to weigh somewhat less in air, weighed the same in that state as when cold, this equality must have arisen from the addition of the weight of the fire present in it. But their experiments were not made with the necessary degree of care.

Buffon, who, by means of the forges belonging to him,

was enabled to make a much greater number of experiments, and on a larger scale, always found that pieces of forged iron, brought to a state of ignition, weighed a little more than when cold; and he fixed the diminution at a 600th part of the weight of the ignited body. But it must be allowed, and Buffon was sensible of it himself, that this experiment could not be decisive; for he has shown, that iron kept for some time at a red heat, continually loses a part of its weight, because it gradually burns: on this account he made further experiments on a substance very common in furnaces, namely slag. He first assured himself that slag retains its weight, or loses only an insensible portion of it, in consequence of being heated and cooled again. He then weighed some of this slag cold, by a very delicate balance; he next brought it to a white heat, and then weighed it a second, and a third time after it had cooled. Five experiments of this kind always gave an excess of weight in the ignited slag, above that which it had when cold, both before and after. This difference amounted to a 580th or a 600th part of that of the piece of slag.

But it may be said, if this be the case, fire is heavier than air; for the specific gravity of slag is to that of water, as 2½ to 1; therefore this gravity is to that of air as 2125 to 1. But the fire contained in a piece of ignited slag, is about a 600th part of its weight; consequently it is to the weight of an equal volume of air, as 3½ to 1, which is not credible. So great is the tenuity of fire, that we can hardly allow ourselves to think that its specific gravity approaches even near to that of air.

But it must be observed, that in an ignited mass, brought to a white heat, a large quantity of fire is accumulated: the weight therefore of fire, in its ordinary state, and in bodies heated to the mean temperature of our atmosphere, may be utterly insensible: but when five

or six hundred times, or more than that quantity, has been accumulated, and to such a degree as to produce ignition, its gravity may then become sensible. Let us suppose, for example, that the fire diffused throughout air, heated to 1 degree of the thermometer, weighs only the 300th part of the weight of that air; when five or six hundred parts more have been introduced into it, to produce ignition, its weight may then equal, and even surpass, the weight of such air as we breathe. We do not know whether this would have been Buffon's answer; but such, in our opinion, is that which might be given.

Those persons however are mistaken, who consider the increase of weight which metals acquire by calcination, as a proof of the heaviness of fire, which by this operation they suppose to become fixed, and in some measure *solidified* along with the metallic calces. It is now known that fire has no part in this augmentation of weight.

Fire dilates bodies: by dilating them, it separates their constituent parts, and at length liquifies them.—This phenomenon, in regard to the effect, is well known. That fire dilates bodies, is well known, as will be shown hereafter by means of a very ingenious machine, which serves to determine the degree and ratio of this dilatation. But it cannot produce this effect without separating the constituent parts of these bodies; and this is the mechanism by which it is afterwards able to liquify, and even to volatilize them; for the solidity of a body is the effect of the mutual adhesion of its constituent parts; an adhesion which, in all probability, is produced by the contact of these moleculæ in large surfaces. But when fire introduced between them, produces a separation, and causes them scarcely to touch each other, the body has then attained to such an extreme degree of fluidity, as to be volatilized.

These particles, having no longer any adhesion, can be

carried away by the least effort, such as that of heat, which continually exercises an action to extend itself in every direction.

There are some bodies however, which fire at first tends to contract: but this is because they contain principles which the fire dissipates: of this kind is clay, which at first shrinks in the fire; but if exposed to a greater degree of heat, it dilates, liquifies, and is changed into glass.

§ II. *Of Air.*

Air is an elastic, heavy fluid, susceptible of compression; which expands by heat, and contracts by cold. It is necessary for maintaining life to all the animals with which we are acquainted; it becomes charged with, and combines with, water, as water combines with it. Such are the principal properties of air, of which we shall here give a general view, and which we shall prove hereafter by some curious experiments.

Air is a heavy fluid.—To discover this property in air, and to prove its existence, requires only a slight knowledge of philosophy. It may be demonstrated by a very simple experiment. Take a glass globe, 6 inches in diameter, furnished with a tube that can be opened and shut by a stop-cock; exhaust it of air by means of a pneumatic machine, and then shut it, so as to exclude the external air; weigh the globe thus exhausted of air by a very nice balance; if you then admit the external air, by turning the cock, the equilibrium will be immediately destroyed, and that end of the balance which supports the globe will preponderate. For a globe of the size above mentioned, 45 or 50 grains must be added to the weight, to restore the equilibrium.

Air is an elastic fluid.—This may be proved by the following very simple experiment. Introduce air into a bladder, but in such a manner as not entirely to fill it. If the bladder be then carried, in that state, to the summit

of a mountain, it will be more and more distended; and by carrying it to the top of a very high mountain, such as the Cordilleras of Peru, it might be made to distend so much as to burst.

The same effect will be produced if the bladder be placed under the receiver of an air pump. For if the receiver be then exhausted of air, on the first stroke of the piston the bladder will swell out, even if it contains only an inch of air; and when the external air is suffered to re-enter the receiver, it will resume its former state.

There can be no doubt that this effect is produced by the elastic force of the air; which, when the pressure of the external air is removed, increases in volume; and when the pressure is restored, it assumes its former state. It is like a spring, more or less compressed by a weight, and which extends itself in a greater or less degree as the weight is heavier or lighter.

Air is a fluid susceptible of compression.—This is a consequence of its elasticity. It is proved by experience, that a double weight compresses it in such a manner as to occupy only one half of its former volume; a quadruple weight reduces it to a fourth part of that volume, and so on. So that it may be said in general that the same mass of air, the temperature remaining the same, occupies a volume which is in the inverse ratio of the compressing weight.

Air expands by heat, and contracts by cold.—This property of air may be proved also by a very simple experiment. In an apartment brought to a mean degree of heat, introduce air into a bladder, but in such a manner as not entirely to fill it. If it be then brought near the fire, so as to be exposed to a degree of heat greater than the mean temperature, we see the bladder distend, and occupy a larger volume. By exposing it to colder air, a contrary effect is produced.

Air is necessary for maintaining animal life.—This truth

is well known. It may be proved in the most evident manner, by shutting up animals in the receiver of an air pump: for as soon as you begin to exhaust it of air, the animals show every sign of uneasiness; they pant for breath, and at length expire, when only a small quantity of air remains. If the air be gradually re-admitted before they are quite dead, they recover life and motion.

Air becomes charged with water, and combines with it; as water, on the other hand, becomes charged and combines with air.—The first part of this proposition is sufficiently proved by facts, with which every one is acquainted. Air is sometimes more and sometimes less humid. Air charged with moisture deposits it in certain bodies, capable of attracting and absorbing it in a great degree; such as salt of tartar, which becomes so much impregnated with it, that it resolves itself into a liquid, merely by the contact of common air, though it has been dried by a violent heat. It is water, disengaged from the air with which it was combined, that occasions the moisture which deposits itself on stones, marble, &c, and during weather distinguished by the appellation of *damp*. The contact of the air alone gradually diminishes the water contained in any vessel, especially if the air be in motion; because a new portion of air is every moment applied to the surface of the water. It is by this mechanism that those winds which have passed over a large extent of sea, as is the case with our west and south-west winds, become charged with water, and are mostly attended with rain.

Water, in its turn, becomes charged with air. This is proved by a curious experiment, made by Mariotte. Take a certain quantity of water, and having freed it as much as possible from air, put it into a small bottle, leaving no vacuity in it but a space of the size of a pea: at the end of twenty-four hours the water will occupy the whole capacity of the bottle. What can have become of the air,

which was in the vacuity, if it has not been absorbed by the water, which was in contact with it?

This property, which air has of combining with water, of even becoming saturated with it, and of afterwards quitting it, is the cause of various physical effects, such as the production of clouds and rain, the rising or falling of the barometer, &c. But these phenomena we shall explain more at length in another place.

§ III. *Of Water.*

The principal properties of this common and well known fluid are as follow: it is transparent, insipid, and inodorous; it always tends to put itself in equilibrio, that is, to assume a form the surface of which is concentric with the earth, a property it possesses in common with all the other heavy and non-elastic fluids; it is incompressible: can be reduced to vapour by heat, carried to a certain degree, and in that state is endowed with a very great elastic force. When exposed to a certain degree of cold, it is transformed into a solid and transparent body: it dissolves salts and a multitude of other substances, and by these means it becomes the vehicle of the nourishing particles both of animals and vegetables, which renders it so essentially necessary in the animal economy, that it is in some measure more difficult to live without water, or without some fluid of which it forms the basis, than without solid aliment.

Such are the properties of water, of which we shall here give a few proofs, till we come to another part of this work, where we shall have an opportunity of enlarging farther on the same subject.

It is needless to adduce any proof that water is transparent, inodorous, and insipid. When this fluid possesses either taste or smell, it is because it holds in solution some foreign bodies. People ought therefore to be suspicious

of water which is said to be agreeable to the taste, as it is certain that it is not pure.

Water always arranges itself in such a form that its surface is concentric with the earth.—Every body is acquainted with this property of water, which it possesses in common with all the other non-elastic fluids, and which is the basis of the art of levelling. When two masses of water communicate with each other, we may rest assured that their surfaces are level, or at an equal distance from the centre of the earth. Those persons then are mistaken, who believe that the water of the Mediterranean is more or less elevated than that of the Red Sea, at the bottom of the Gulph of Suez, which, as is said, caused the plan for cutting through the isthmus to be abandoned, lest the Mediterranean should run into the Red Sea, or the latter into the former. Nothing can be more absurd, since these two seas have a communication with each other by the ocean. Had they been originally created on a different level, they would not have failed soon to assume the same level.

Water is incompressible.—The members of the Academy *del Cimento*, the first who it appears adopted the true method of philosophizing, namely, by subjecting every thing to the test of experiments, made a very curious one, which proves this property of water. They inclosed a quantity of water in a hollow ball of gold, of a certain considerable thickness, taking care to ascertain that the cavity was completely filled; they then subjected the ball to the blows of a hammer, by which means its capacity was diminished; but the water, instead of suffering itself to be compressed, passed through the pores of the gold, though exceedingly small. This experiment was repeated by Mr. Boyle and by Muschenbroek, who both attest the truth of it.

Water by a certain degree of heat is reduced into highly elastic vapour. This truth may be proved also by very simple experiments. If a small quantity of water be thrown

upon a strong fire, you will immediately see it transformed into vapour.

If water be kept in a state of violent ebullition in a close vessel, there arises from it an elastic vapour of so great force, that unless a vent be opened for it, or if the vessel be not sufficiently strong to resist its action, it will undoubtedly burst: for this reason, in the boiler of the steam-engine there is a valve, which must be opened when the steam has acquired a certain force, otherwise it would be shivered to pieces.

This vapour, according to the calculations made by philosophers, occupies a space 14000 times greater than the water which produced it. Hence arises the prodigious force it acquires when confined in a much less space.

Water, when exposed to a certain degree of cold, is transformed into a solid transparent body, which we call ice. This fact is so well known, that it is needless to prove it. We shall therefore confine ourselves to an explanation of this singular effect.

It is fully proved, by the formation of ice, that the primitive state of water was that of a solid body. It is a solid fused by a degree of heat far below that which, according to our sensations, we call *temperate;* for it would be a strange error to imagine, that what we call zero of the thermometer, is the absence of all heat. Since spirit of wine, and various other liquors, remain fluid at degrees of cold much greater than that which freezes water, it is evident that the degree called zero, which is marked 0, is merely a relative term, the commencement of the division.

Water then is only a liquified solid, which keeps itself in a liquid state at a degree of heat very little more than that marked 0, on our common thermometers, and which in that of Fahrenheit is marked 32. The reason of this we shall explain when we come to speak of thermometers.

Let us now take a short view of water in its solid state.

When heated to a certain degree, the matter of fire, with which it is then impregnated, raises up, and separates from each other, the moleculæ of which it is composed; for as these moleculæ do no longer touch each other by so large surfaces, though still within the limits of adhesion, they easily run one over the other. Thus we have ice brought to a state of fusion, as lead is by a heat of 226 degrees. The matter of fire escapes to diffuse itself in equilibrium in other bodies, which have less, for it is in this manner that cooling is effected; these moleculæ approach each other; they come in contact by the small facets which they reciprocally present, thus adhere and form a solid body What is here said, in regard to the small facets of the particles of water, seems to be proved by the ramifications of ice, for these ramifications, both in ice and in snow, are always formed under angles of 60 or 120 degrees; which indicate planes uniformly inclined. We shall enlarge farther, in another place, on this phenomenon, which depends on crystallization.

It would be ridiculous, at present, to explain the formation of ice by the supposed frigorific particles, the existence of which seems to rest on no foundation. Water freezes at a degree of heat which can no longer keep it in fusion; for the same reason, and by the same mechanism, that lead becomes fixed at a degree of heat less than 226 of Reaumur. But the same philosophers who, to explain the congelation of water, have recourse to the frigorific particles diffused throughout the atmosphere, do not recur to them in the present case: they well know that the fixation of lead arises only from the particles, which the fire does not keep sufficiently separated, approaching each other. Why then should we recur to any thing else in regard to the congelation of water?

It is indeed true, that in the congelation of water there is one phenomenon exceedingly singular, which is, that water decreases in volume in proportion as it cools, at

least to a certain degree; but at the moment when ice is formed, this volume increases very sensibly; hence the philosophers above mentioned conclude, that some foreign matters, or their supposed frigorific particles, have been introduced into it. But we shall observe, 1st. That the case is the same with iron. 2d. That this is the effect of crystallization; for we must here repeat, that the congelation of water is merely a crystallization, by which its moleculæ assume an arrangement which is determined by their primitive form. But this arrangement cannot be effected without producing an increase of volume, as happens in regard to iron when it becomes fixed, or loses its fluidity, merely by the diminution of heat, which kept it in fusion. This will become more evident when we have explained the phenomena of crystallization.

Water dissolves salts and a variety of other substances.—Every one knows that all saline bodies, whether acids, alkalis, or neutral salts, are soluble in water, in a greater or less quantity; and a very singular phenomenon in this respect is, that water which holds in solution as much of a certain salt as it can contain, will still dissolve some other salt. But, for the most part, it abandons one of them when it becomes charged with the other, if it has a greater affinity for the latter.

Of the other substances, which water dissolves, we shall mention in particular the gummy or mucilaginous part of animals or vegetables, which forms the nourishment of the former. It is in consequence of this property, that water is so useful to the animal economy; for the nutritive part of aliment must be dissolved and diluted in water, or some other fluid of the same kind, before it is swallowed, or this solution must be effected in the stomach after deglutition. Hence it is that water, in some measure, is the first aliment of man and of animals. It is not an aliment itself, but it is the vehicle of every thing that serves as aliment.

Finally, water is the base of all the other aqueous fluids,

such as spirits, oils, &c; for water may be extracted from all of them by a very simple process, namely distillation. Combustion produces the same effect by disengaging the matter purely aqueous.

§ IV. *Of Earths.*

Earth is that part of compound bodies, which remains fixed after they are analyzed. When, by the action of fire, we have consumed or raised in exhalations the inflammable part, have expelled or driven the air into the atmosphere, have raised the water in vapours, there remains a solid and fixed body, not farther alterable by fire, that is the elementary earth, the different kinds of which it is that commonly constitutes the nature of the mixture.

It must indeed be acknowledged, at least till we arrive at a decomposition beyond that of the fixed body, that this elementary earth is not all of the same kind; contrary to which, it is found that all water, all respirable air, is homogeneous: for where, by calcination, for instance, we have reduced a metal to calx, which is vitrifiable, that calx or earth is not necessarily homogeneous, neither to another metallic calx, nor to caput mortuum, or to the earth of another body, as the calx of stone, or the earth of any vegetables or animal calces. The proof of this is simple; for metallic calx being revivified by the addition of phlogiston, produces only the same metal which had given the calx; and, by whatever way we proceed, the earth of any other compound will not yield a metal, however we may combine it. This property of metallic calx, is the basis of the art of separating the metals from the earths and stones with which they are mineralized; for as soon as their calces, vitrified by the violence of fire, come in contact with the carbonic matter, those of metals regain their metallic form, and disengage themselves by their weight from the vitrified calces of the other heterogeneous bodies with which they were confounded.

It has been usual to distinguish earths into calcareous, vitrifiable, and refractory. Calcareous earths are those which, burned in the fire, reduce into a calx. The properties of this calx are well known, the principal characteristic of which is that of attracting and absorbing moisture violently, and of effervescing with water. But it is not necessary to subject them to that test to know them: they are easily distinguished by exposing them to the action of any gentle acid. Calcareous earths dissolve with more or less effervescence; whereas other earths suffer no dissolution.

Vitrifiable earths are those which, exposed to a fire more or less active, suffer a fusion, and become more or less fluid.

The refractory earths, are those on which the most violent heat excited in our furnaces produces no effect or alteration.

We say the most violent heat excited in our furnaces; for perhaps, if all the earths are not found to be vitrifiable, this happens only because we have not been able to produce a sufficient degree of heat. In fact, in proportion as we have succeeded in producing more considerable degrees of heat, we also are able to vitrify materials which had resisted the former degrees of fire. But it is a remarkable circumstance, that some earths which separately are unfusible, on being mixed together become fusible and vitrifiable. Thus, for example, calcareous earth, mixed with argil, runs and becomes glass. Usually, metallic matters, mixed either with calcareous earths, or with refractory, as pure argil, communicate to them also fusibility, which these have not separately.

We shall limit ourselves here as to what might be said concerning the elements; what has been now said being the most solid and best proved part of the subject. We shall now pass on successively through all the branches of physics, in selecting what they offer the most curious and

interesting. We have already said we shall hardly regard much order in these observations: from the bowels of the earth, we shall sometimes suddenly raise ourselves to the upper regions of the atmosphere; from a problem in the celestial physics, we shall pass to a question in mineralogy. We shall treat apart on electricity, on magnetism, and on chemistry, because these branches of philosophy are extremely fertile in curious experiments, and present each of them materials enough for separate treatises.

PROBLEM I.

Construction of the Pneumatic Machine, or Air Pump, with an account of the principal experiments in which it is employed.

Air being an elastic fluid, it may be easily conceived that if it be shut up in a close vessel, and if to this vessel be adapted a pump, made to communicate with it, when the piston is drawn up, the air contained in the vessel will enter the body of the pump. If the communication between the vessel and the body of the pump be then intercepted, and if that between the latter and the external air be opened, by pushing down the piston, the air contained in the body of the pump will be expelled. If the communication between the body of the pump and the external air be then shut, and that between the body of the pump and the vessel be opened, when the piston is drawn up, the air in the vessel will again rush into the body of the pump; and by thus repeating the same operation as before, the whole air contained in the vessel will be evacuated. If the body of the pump be equal, for example, to the capacity of the vessel with which it communicates, the first operation will reduce the air to one half of its density; the second to the half of that half, or to a fourth, and so on in succession: hence a very few strokes of the piston will re-

duce the air contained in the vessel to a very great degree of tenuity.

Such is the mechanism of the air pump, of which the following is a more minute description. AB, pl. 1 fig. 1, is a cylindric pump or barrel, in which the piston D is made to play by means of the branch or handle DC, having at its extremity a stirrup for receiving the foot, by means of which it can be forced downwards. The body of the pump is fitted into a collar from which proceed three or four branches that form a sort of stand. From the top of the pump A there arises a tube, about an inch in diameter, to the upper part of which is adapted a circular plate, with a small raised border or rim around it. On this plate is placed the receiver, in the form of a bell. The small tube above mentioned, which serves to establish a communication between the vessel and the body of the pump, generally passes through this plate, and has a screw at the end, in order that the tube of another vessel, such as a bell or small balloon, from which it is required to evacuate the air, may be screwed upon it. Beneath the plate, and between it and the body of the pump, is a stop-cock I, so constructed that, by turning it to one side, a communication is established between the body of the pump and the receiver, while all communication is prevented between it and the exterior air; and by turning it in a contrary direction a contrary effect is produced. Such is the form of the pneumatic machine; at least of certain simple kinds of it, for there are others more complex. One kind, for example, consists of two cylinders, the pistons of which are alternately worked by means of a crank; so that one of them always becomes filled with air from the receiver, while the other throws out into the atmosphere the air it contained. But it is needless to enter into these details: those who are desirous of seeing the newest improvements in regard to air pumps, may have recourse to the different

treatises on natural philosophy, where they will find a description and figures of the different additions made to this machine by mechanics and philosophers, to render the use of it more convenient or more general.

By combining this description with what has been said in regard to the air, it will be easy to conceive in what manner this machine is employed. When a bell-formed receiver is used, a piece of oiled leather, with a hole in the middle of it to afford a passage to the tube H, is sometimes placed on the plate FG. This wet leather causes the contact of the edges of the receiver to be more exact, than if it rested on metal; for some aperture or cleft would often remain, through which the exterior air would introduce itself. The receiver is then placed upon the plate, with or without the leather, and the cock is turned in such a manner as to open a communication between the body of the pump and the receiver. The piston, which we suppose raised up to the top, is then forced down by pressing the foot on the stirrup, and when it is as low as possible the cock is turned in such a manner as to intercept the first communication, and establish that between the body of the pump and the exterior air; the piston being then raised, the air in the body of the pump is expelled, and the cock is turned in the contrary direction which shuts the second communication, and opens the former; the piston is then forced down again, and the same effect takes place. Or the pump is otherwise worked in the manner peculiar to its form and construction. Every stroke of the pump expels a portion of the air originally contained in the receiver, and in a decreasing geometrical progression. Thus, for example, if the body of the pump is equal in capacity to the receiver, the first stroke of the piston will expel one half of the air contained in the receiver; the second will expel the fourth part; the third the eighth part; the fourth the sixteenth part, &c; so that it may with truth

be said that it can never be entirely evacuated; but after fourteen or fifteen strokes of the piston, it will be so rarefied, that there will remain only a part infinitely small; for, on the above supposition, the quantity of air remaining after the first stroke of the piston will be $\frac{1}{2}$, after the second $\frac{1}{4}$, after the third $\frac{1}{8}$, and so on; after the fifteenth, then, it will be only the 32768th part, which in general is equivalent to a perfect vacuum, for experiments such as those that are usually made.

After these observations on the form and use of the pneumatic machine, we shall proceed to a few of the most curious experiments.

EXPERIMENT I.

Place on the plate of the machine a receiver in the form of a bell: if you try to remove it, you will experience no resistance; but if you give only one stroke with the piston, it will adhere to the plate with considerable force: after 2, 3, or 4 it will adhere with more force; and after 18 or 20 with the force of several hundred pounds weight. If the base of the receiver be, for example, a circle a foot in diameter, the adhesive force will be about 1617 pounds.

This experiment is a proof of the gravity of the air of the atmosphere; for the air is the only body which, by pressing on the receiver, can produce the adhesion experienced. When the air under the receiver is as dense as the external air, there is no adhesion, the air within and without being then in equilibrio with each other; but when that within is evacuated, either in whole or in part, the equilibrium is destroyed, and the external compresses the receiver against the plate on which it rests, with the excess of the weight it has over the force of the internal air. It will be found that this force is equal to that of a cylinder of water 33 feet in height, and having a base equal to that of the receiver. It was by these means that we found the

result of 1617 pounds; for a cylindric foot of water weighs 49 pounds; consequently 33 feet weigh 1617.

EXPERIMENT II.

Place under a receiver an apple, much shrivelled, or a very flaccid bladder, in which there remains but a small quantity of air. If the receiver be then exhausted, you will see the skin of the apple become distended, so that it will assume almost the same form, and have as fresh an appearance, as it had when plucked from the tree. The bladder will, in like manner, swell up, and may even be distended to such a degree as to burst. When the air is re-admitted into the receiver, they will both resume their former contracted state.

We have here an evident proof of the elasticity of the air. While the wrinkled apple or flaccid bladder is immersed in atmospheric air, its weight counteracts the elastic force of the air contained in both; but when the latter is freed from the weight of the former, its elasticity begins to act, and by these means it distends the sides of the vessel which contains it. When the air is re-admitted, the elasticity is counteracted as before, and the apple and bladder resume their former shape.

EXPERIMENT III.

Place under the receiver a small animal, such as a cat, or a mouse, &c. If you then pump out the air, you will immediately see the animal become troubled, swell up, and at length expire, distended and foaming at the mouth. These phenomena are the effect of the air contained in the animal's body, which being no longer compressed by the external air, exercising its elasticity, it distends the membranes, and throws out the humours which it meets with in its way.

EXPERIMENT IV.

If butterflies or common flies be placed under the receiver, you will see them fly about as long as the air contained in the machine is similar to the external air; but as soon as you have given a few strokes with the piston, they will in vain make efforts to rise, as the air has become too much rarefied to support them.

EXPERIMENT V.

Adapt to a flat bottle a small tube, so constructed that it can be screwed upon the end of the tube, which rises above the plate of the machine. On the second or even the first stroke of the piston, you will see the bottle burst; for this reason it ought to be covered with a piece of wire netting, to prevent the fragments of it from doing mischief by flying about.

The same effect is not produced on a receiver, because its spherical form gives it strength, in the same manner as an arch, to resist the pressure of the exterior air.

EXPERIMENT VI.

Provide a small machine consisting of a bell and hammer, the latter of which can be put in motion by wheel work, so as to strike the bell and make it sound. Wind up this small machine, and having put it in motion, place it below the receiver, and exhaust the air. As the air is exhausted, you will hear the sound of the bell always become weaker; and if you continue to exhaust the air, the sound will at length cease entirely, or be scarcely heard. On the other hand, if you begin to readmit the air, the sound will be revived, and will increase more and more.

This experiment, which we have mentioned in another place, fully proves that air is absolutely necessary for the transmission of sound, and that it is the vehicle of it.

EXPERIMENT VII.

Provide a receiver with a hole in the top, and through this aperture introduce the tube of a barometer, so that the bulb shall be in the inside of the receiver: then close the remaining aperture with mastic, or with a metal plate, so as to exclude the external air. Place the receiver thus prepared on the plate of the instrument, and begin to exhaust it of air. On the first stroke of the piston you will see the mercury fall considerably: a second stroke will make it still fall, but a quantity less than the former; and so on in a decreasing proportion. In short, as the air in the receiver becomes less, the mercury will descend more and more towards the level of that in its bason.

EXPERIMENT VIII.

Provide two hollow hemispheres of brass or copper, two feet in diameter, more or less, with very smooth edges, so that they can be fitted to each other, in such a manner as to form a hollow globe. To one of these hemispheres let there be adapted a tube passing into the inside of it, furnished with a stopcock, and constructed in such a manner that it can be screwed on the end of the tube H of the pneumatic machine. Each of these hemispheres must have affixed to it a ring, or handle, by one of which the globe can be suspended, while a weight is attached to the other.

When these arrangements are made, adapt the two concave hemispheres to each other, so that the edges may be in perfect contact. Screw upon the end of the tube H of the pneumatic machine, the end of that which communicates with the inside of the globe, and exhaust it of air as much as possible, by forty, fifty, or more strokes of the piston. Then shut the communication between the inside of the globe and the external air, by turning the stopcock, and remove the globe from the machine. If you

then suspend the globe by one of the rings, and attach a considerable weight to the other, you will find that the weight will not be able to separate the two hemispheres. If the globe indeed be two feet in diameter, and well exhausted of air, the force with which the edges are pressed together, will be equal to about 6500 pounds.

This is what is called the celebrated experiment of Magdeburgh, because first made by Otto Guerik, a burgomaster of that town. He applied to the globe several pairs of horses, some dragging in one direction and some in another, without their being able to separate the two hemispheres: and in this there is nothing astonishing, for though six horses draw a waggon, loaded with a weight equal to several thousand pounds, it is well known that, one with another, they do not exert a continued effort greater than about 180 pounds, and, dragging by jerks, their exertion does not exceed perhaps 4 or 500 pounds. The effort of six horses, therefore, is equal to no more than 3000 pounds. We shall even suppose it to be 4 or 5000 pounds; but if the six horses draw in different directions, they do not double that force; they only oppose to the first the resistance necessary to make it act, and do nothing more than what would be done by a fixed obstacle to which the globe might be attached. It needs therefore excite no surprise that, in the experiment of Magdeburgh, twelve horses were not able to disjoin the hemispheres; for according to this disposition, these twelve horses were equivalent only to six; and it has been shown that the effort of these six horses, according to the above calculation, was very inferior to that which they had to overcome.

PROBLEM II.

To invert a glass full of water, without spilling it.

Pour water or any liquor into a glass, till it is full to

the edge, and place over it a square bit of pretty strong paper, so as to cover the mouth of it entirely; and above the paper place any smooth body, such as the bottom of a plate, or a piece of glass, or even your hand. If you then invert the whole, and afterwards raise it up, you will see the paper adhere to the glass, and the water will not fall out.

This effect is produced by the gravity of the air; for as the air presses on the paper, which covers the mouth of the glass, with a weight superior to that of the water, it must necessarily support it. But as the paper becomes moist, and affords a passage to the air, it at length suddenly falls down.

REMARK.—In consequence of the same principle, water or any other liquor may be drawn from a vessel, by means of a pipe open at both ends. For, let AB, pl. 1 fig. 2, be a tube, thick in the middle, and tapering towards both ends, which terminate in two pretty narrow apertures. Immerse it in any liquor with both ends open until it is full; and then place your finger on the upper end, so as to close the aperture; if you then draw it from the fluid, the liquor it contains will remain suspended in it, though the lower end be open; and it will not flow out till you remove your finger from the upper orifice.

Instead of employing a tube like that above described, you may use a vessel, such as HB, fig. 3, made like a bottle, and having its bottom pierced with a great number of small holes. If you immerse this vessel in water with the bottom downwards, the liquor will enter through the holes and fill it; and if you then place your finger on the mouth of it, and draw it from the fluid, the water will remain suspended in it as long as your finger continues in that situation; but as soon as it is removed, the water will run out.

This is what is called the *clepsydra* or *watering pot* of

Aristotle: but neither Aristotle, nor any of those philosophers who followed him, till the time of Torricelli, assigned a better reason for this effect, than the horror which nature, as they said, had of a vacuum.

PROBLEM III.

To draw off all the liquor contained in a vessel, by means of a syphon.

The name *syphon* is given to a tube or pipe, consisting of two branches, AB and CD, pl. 1 fig. 4, united by a crooked part BC. Whether this part be straight or bent is of no importance. It has sometimes an aperture which serves for filling the two branches, or for sucking up the liquor in which the shorter branch is immersed, while the other is shut. It is employed in the following manner, for solving the problem proposed.

Having filled the two branches of the syphon with liquor, close them with your fingers, and immerse the shorter one in the vessel, so that the end of it shall almost touch the bottom; then remove your finger from the end of the longer branch, which will be lower than the bottom of the vessel to be emptied, and you will see the liquor run out at the extremity D of this branch, till the vessel is entirely emptied. Or the syphon may be filled and set a-running after it is placed in the liquid, by sucking the air out at the lower end with your mouth.

This phenomenon is also an effect of the gravity of the air: for when the syphon is full of liquor, and placed as above described, the air by its weight exercises a pressure on the surface of the liquor to be emptied, and at the same time on the orifice of the lower branch. The latter pressure indeed is for this reason somewhat superior to the former; but as this branch is full of a liquor heavier than air, the advantage must be in its favour, and the column ought to fall down. At the same time the air pressing on the sur-

face of the fluid in the vessel, forces the liquor into the branch of the syphon immersed in it; which furnishes a new supply to the longer one, and so on in succession, till the whole liquor is exhausted.

REMARKS.—I. All the wine contained in a cask might easily be drawn off in this manner by the bung-hole; and this indeed is the method employed in some places for transferring liquor from one cask to another, without disturbing the lees, which are at the bottom.

II. By the same means, water may be conveyed from any place to another on a lower level, making it pass over an obstacle higher than either, provided the place which the water has to surmount is not higher than 32 or 33 feet above the level where it begins to ascend; for it is well known that the gravity of the atmosphere cannot support a column of water greater than 32 or 33 feet. It is even necessary that the obstacle should be several feet less in height than 32 feet above the level of the water to be raised, otherwise the water will move in a very slow manner, unless the orifice of the longer branch be much lower than that level.

This is a very economical kind of pump, and might be employed to convey water from one place to another when it is impossible or inconvenient to pierce an intervening obstacle, to establish a pipe of communication. As we have never made the experiment, we cannot venture to give this as a very certain method, on account of the air which might lodge itself at the summit of the bending of the pipe.

It is on the property of the syphon also that the following hydraulic amusements depend.

PROBLEM IV.

To construct a vessel which, when filled to a certain height with any liquor, shall retain it; and which shall suffer the

whole to escape, when filled with the same liquor to a height ever so little greater.

Those who may be desirous of giving to this small hydraulic machine a more mysterious air, add to it a small figure, which they call Tantalus, because in the attitude of drinking; but as soon as the water has reached its lips, it suddenly runs out. The construction of this machine is as follows.

Let there be a metallic vessel ABCE, pl. 1 fig. 5, divided into two parts by a partion F*f*: in the middle of this partition is a small round hole, to receive a tube MS, about two lines in diameter, the lower orifice of which must descend a little below the partition. This tube is covered by another somewhat larger, closed at the top, and having on one side, at the bottom, an aperture, so that when water is poured into the vessel, it may force itself between the two tubes, and rise to the upper orifice S of the first. This mechanism must be concealed by a small figure in the attitude of a man stooping to drink, and having its lips a little above the orifice S.

If water be poured into this vessel, as soon as it reaches the lips of the figure, being above the orifice S, it will begin to run off; and a kind of syphonic motion will take place, in consequence of which the whole of the water will run into the lower cavity, which ought to have in the side, towards the partition, an aperture to let the air escape at the same time.

This hydraulic machine might be rendered still more agreeable, by constructing the small figure in such a manner, that when the water has attained to its utmost height, it shall cause the figure to move its head, in order to approach it; which would represent the gestures of Tantalus, endeavouring to catch the water to quench his thirst.

PROBLEM V.

Construction of a vessel which while standing upright retains the liquor it contains; but which if inclined, as for the purpose of drinking, immediately suffers it to escape.

Pierce a hole in the bottom or side of the vessel to which you are desirous of giving this property, and insert in it the longer branch of a syphon, the other extremity of which must reach nearly to the bottom, as seen pl. 1 fig. 6. Then fill the vessel with any liquor, as far as the lower side of the bent part of the syphon: it is evident that when inclined, and applied to the mouth, this movement will cause the surface of the water to rise above the bending, and from the nature of the syphon the liquor will then begin to flow off; and if the vessel is not restored to its former position will continue doing so till it becomes empty.

This artifice might be concealed by means of a double cup, as it appears fig. 7; for the syphon *abc*, placed between the two sides, will produce the same effect. If the vessel be properly presented to the person whom you are desirous of deceiving, that is to say in such a manner as to make him apply his lips to the side *b*, the summit of the syphon, the inclination of the liquor will cause it to rise above that summit, and it will immediately escape at *c*. Those persons however who are acquainted with the artifice will apply their lips to the other side, and not meet with the same disappointment.

PROBLEM VI.

Method of constructing a fountain, which flows and stops alternately.

This fountain, the invention of M. Shermius, is exceedingly ingenious, and affords a very amusing spectacle, because it seems to flow and to stop at command. It depends

on the operation of a syphon, which, by the peculiar mechanism of this machine, is sometimes obstructed and sometimes left free, as will appear by the following description.

AB pl. 2 fig. 8, is a vessel shaped like a drum, and close on all sides, except a hole in the middle of the bottom F, into which is soldered a tube CD, open at both its extremities C and D; but the upper one C ought not to touch the top of the cylinder, in order that the water may have a free passage. When this vessel is to be filled, it must be inverted, and the water is then introduced through the aperture D, till it is nearly full.

From the centre of the bottom of a cylindric vessel, GH, somewhat larger, rises a tube DE, a little narrower, so that it can be fitted exactly into the former. Its height also ought to be somewhat less; and its summit E must be open. These two tubes, CD and ED, have two corresponding holes, I, *i*, at an equal height above the bottom of the lower vessel, so that when the one tube is inserted into the other, the holes may be made to correspond, and establish a communication between the external air and that in the upper vessel. Lastly, there must be two or four holes, as K, L, in the bottom of the vessel AB, through which the water may flow into the lower vessel GH; and in this vessel also there ought to be one or two holes, M, N, of a smaller size, through which the water may escape into another large vessel placed below the whole apparatus.

To make the machine play, pour water into the vessel AB, till it is almost entirely full; having then stopped the pipes K and L, introduce the tube DE into CD, so that the vessel GH shall serve as a base, and make the two holes I and *i* correspond with each other; if the holes or pipes K and L be then unstopped, as the external air will have a communication, by the apertures I, *i*, with that which is above

the water in the vessel AB, the water will flow readily into the vessel GH: but the quantity which escapes from GH being less than that which falls from the upper vessel AB, it will soon rise above the apertures I, *i*, and intercept the communication between the external air and that at the top of the vessel AB; consequently the water will soon after cease to flow. But as the water will continue to flow from the lower vessel while no more falls into it from the upper one, the apertures I, *i*, will soon be uncovered, and the above communication will be re-established: the water therefore will again begin to flow through the pipes K and L, and, rising above the apertures I, *i*, will soon after begin to escape again; and this play will take place alternately, till no more water is left in the vessel AB.

The time when the air is about to be introduced through the apertures I, *i*, into the top of the vessel AB, will be known by a small gurgling noise; and at that moment you must command the fountain to flow. When you see the water begin to sink below the same apertures I, *i*, you must command it to stop. Hence the name given to this machine, *the fountain of command.*

PROBLEM VII.

How to construct a clepsydra, which indicates the hours by the uniform efflux of water.

We have shown, in the mechanics, that if a vessel has a hole in its bottom, the water flows out faster at first than it does afterwards, so that if we wished to employ the efflux of water to indicate the hours, as the ancients did, it would be necessary to make the divisions very unequal; because, if the whole height were divided into 144 equal parts, the highest, if the vessel were cylindrical, ought to contain 23, the second 21, &c, and the last only 1.

Are there any means then of causing the water to flow off in a uniform manner? This is a problem which natu-

rally presents itself in consequence of the preceding observation. We have already solved it in mechanics, by showing what form ought to be given to the vessel, that the efflux of the water through a hole in its bottom may be uniform. But we shall here give a more perfect solution, as it is equally exact whatever may be the law of the retardation of the velocity of the water.

This solution is founded on the property of the syphon, and is very old, since it was described by Hero of Alexandria. It is as follows.

Provide a syphon ABC pl. 2 fig. 9, and affix to the shorter branch AB a piece of cork, capable of keeping the whole syphon in a vertical situation, as seen in the figure. When this apparatus is made to play, and the water begins to flow off through the longer branch, it will continue to escape with the same velocity, whatever may be the height of the water: for, in this machine, the efflux takes place in consequence of the inequality of the force with which the atmosphere presses on the surface of the liquid, and on the orifice of the longer branch; since the syphon then sinks down as the surface of the liquid falls, it is evident that the velocity of its efflux will be uniform.

If the height of the vessel DE be therefore divided into equal parts, these divisions will indicate equal intervals of time. To render this clepsydra more curious, the branch AB might be concealed, by a small light figure made to float on the surface of the water in the vessel, and indicating the hour with a rod, or its finger, on a small dial plate.

On the other hand, the water might be made to flow from any vessel whatever, through a similar syphon, into another vessel of a prismatic or cylindric form, from which might arise a small figure floating on the water, to indicate the hour as above described.

PROBLEM VIII.

What is the greatest height to which the Tower of Babel could have been raised, before the materials carried to the summit lost all their gravity?

To answer this mathematical pleasantry, which belongs as much to the physical part of astronomy as to mechanics, we must observe:

1st. That the gravity of bodies decreases in the inverse ratio of the squares of their distance from the centre of the earth. A body, for example, raised to the distance of a semi-diameter of the earth above its surface, being then at the distance of twice the radius, will weigh only $\frac{1}{4}$ of what it weighed at the surface.

2d. If we suppose that this body partakes with the rest of the earth in the rotary motion which it has around its axis, this gravity will be still diminished by the centrifugal force; which, on the supposition that unequal circles are described in the same time, will be as their radii. Hence at a double distance from the earth this force will be double, and will deduct twice as much from the gravity as at the surface of the earth. But it has been found, that under the equator the centrifugal force lessens the natural gravity of bodies $\frac{1}{289}$th part.

3d. In all places, on either side of the equator, the centrifugal force being less, and acting against the gravity in an oblique direction, destroys a less portion, in the ratio of the square of the co-sine of the latitude to the square of radius.

These things being premised, we may determine at what height above the surface of the earth a body, participating in its diurnal motion in any given latitude, ought to be to have no gravity.

But it is found by analysis that under the equator, where the diminution of gravity at the surface of the earth, oc-

-casioned by the centrifugal force, is exactly $\frac{1}{289}$, the required height, counting from the centre of the earth, ought to be $\sqrt[3]{289}$, or 6 semi-diameters of our globe plus $\frac{61}{100}$, or 5 semi-diameters and $\frac{61}{100}$ above the surface.

Under the latitude of 36 degrees, which is nearly that of the plains of Mesopotamia, where the descendants of Noah first assembled, and vainly attempted, as we learn from the Scriptures, to raise a monument of their folly, it will be found that the height above the surface of the earth ought to have been $6\frac{17}{100}$ semi-diameters of the earth.

Under the latitude of 60 degrees, this height above the surface of the earth ought to have been $9\frac{47}{100}$ semi-diameters of the earth.

Under the pole this distance might be infinite; because in that part of the earth there is no centrifugal force, since bodies at the pole only turn round themselves.

PROBLEM IX.

If we suppose a hole bored to the centre of the earth; how long time would a heavy body require to reach the centre, neglecting the resistance of the air?

As the diameter of the earth is about 7930 miles, the semi-diameter will be 3965 miles, or 20935200 feet. If the acceleration were uniform, the solution of the problem would be attended with no difficulty; for nothing would be necessary but to say, according to Galileo's rule, As $16\frac{1}{12}$ feet are to 20935200 feet, so is the square of 1 second, which is the time employed by a heavy body in falling $16\frac{1}{12}$ feet, to a fourth term, which will be the square of the number of seconds employed in falling 20935200 feet. But this fourth term will be found to be 1301940; and if we extract the square root of it, we shall have the required number, that is 1141 seconds, or 19 minutes. Such, according to this hypothesis, would be the time

employed by a heavy body in falling to the centre of the earth.

But it is much more probable that a body, proceeding along the radius of the earth, would lose its gravity, as it approached the centre; for at the centre it would have no gravity at all; and it can be demonstrated, supposing the density of the earth to be uniform, and that attraction is in the inverse ratio of the squares of the distances, that the gravity would decrease in the same proportion as the distance from the centre. The problem therefore must be solved in another manner, founded on the following proposition demonstrated by Newton:

If a quadrant be described with a radius equal to that of the earth, an arc which has $16\frac{1}{12}$ feet for versed sine, will be to the quadrant, as 1 second employed to pass over in falling these $16\frac{1}{12}$ feet, is to the time employed to fall through the whole semi-diameter of the earth.

But an arc of the earth corresponding to $16\frac{1}{12}$ feet of fall, or versed sine, is 4′ 16″ 5‴; and this arc is to the quadrant, as 1 to 1265·2. Consequently we have this proportion, as 4′ 16″ 5‴ are to 90°, or as 1 to 1265·2, so is 1 second, employed in falling $16\frac{1}{12}$ feet at the surface of the earth, to 1265″ 12‴, or 21′ 5″ 12‴. This will be the time employed by a heavy body in falling from the surface of the earth to the centre, according to the second supposition, which is more consistent with the principles of philosophy than the former.

PROBLEM X.

What would be the consequence, should the moon be suddenly stopped in her circular motion, and in what time would she fall to the earth?

As the moon is maintained in the orbit which she describes around the earth, only by the effect of the centrifugal force which arises from her circular motion, and

which counterbalances her gravitation towards the earth, it is evident that, if the circular motion were annihilated, the centrifugal force would be annihilated also; the moon then would be abandoned to a tendency towards the earth, and would fall upon it with accelerated velocity.

But this motion would not be accelerated according to the law discovered by Galileo; for this law supposes that the force of gravity is uniform, or always the same. In the present case the gravity of the moon towards the earth would vary, and be increased in the inverse ratio of the square of the distance, according as she approached the centre; which renders the problem much more difficult.

Newton however has taught us the method of solving it: this philosopher has shown, that this time is equal to the half of that which the same planet would employ to make a revolution around the same central body, but at half her present distance from it. Now it is well known that the lunar orbit is nearly a circle, the radius of which is equal to 60 semi-diameters of the earth, and her revolution is 27 days 7 hours 43 minutes*; hence it is found, by the celebrated rule of Kepler, that if she were distant from the earth only 30 of its semi-diameters, she would employ in her revolution around it no more than 9 days 15 hours 51 minutes. Consequently her semi-revolution would be 4 days 19 hours 55½ minutes, which is therefore the time the moon would employ in falling to the centre of the earth.

REMARK.—If we examine, by the same method, in what time each of the circumsolar planets, under the like cir-

* We make the revolution of the moon 27 days 7 hours 43 minutes, and not 29 days 12 hours 44 minutes; for the revolution here meant, is from any point of the heavens to the same point again, and not a synodical revolution, which is longer; because when the moon has described a complete circle, she has still to come up with the sun, which in the course of 27 days has advanced in appearance 27 degrees or nearly.

cumstances, would fall into the sun, it will be found that

	D.	H.
Mercury would fall in . .	15	13
Venus in . . .	39	17
The Earth in . . .	64	10
The Moon in . . .	64	10
Mars in	121	10
Jupiter in . . .	766	6
Saturn in . . .	1902	0
The Georgian planet in . .	5433	17

PROBLEM XI.

What would be the gravity of the body transported to the surface of the sun, or any other planet than the earth, in comparison of that which it has at the surface of our globe?

It can be demonstrated, to all those capable of comprehending the proofs, that the gravity of a body at the surface of the earth, is nothing else than the tendency of that body towards every part of the earth; the result of which must be a compound tendency passing through the centre, provided the earth be a perfect globe, which we here suppose, on account of the small difference between its figure and that of a sphere. It can be demonstrated also, that as attraction takes place in the direct ratio of the masses, and the inverse ratio of the square of the distances, a particle of matter placed on the surface of a sphere, which exercises on it a power of attraction, will tend towards it with the same force as if its whole mass were united in its centre.

It thence follows, that if we suppose two spheres, unequal both in their diameters and masses, the gravity of the particle on the one, will be to that of the same particle on the other, in the compound ratio of their masses taken

directly, and of the squares of their semi-diameters taken inversely.

But it has been demonstrated by astronomical observations, that the sun's semi-diameter is equal to about 111 of the earth's semi-diameters, and that his mass is to that of the earth, as 341908 to 1: the gravity then of a body at the surface of the sun, will be to that of the same body at the surface of the earth, in the compound ratio of 341908 to 1, and of the inverse of the square of 111 to 1, that is of 12321 to 1.

If the number 341908 be therefore divided by 12321, we shall have $27\frac{3}{4}$ nearly; consequently a body of a pound weight, transported to the surface of the sun, would weigh $27\frac{3}{4}$ pounds.

But we shall endeavour to illustrate this subject by a reasoning still simpler. If the whole mass of the sun, which is 341908 times as great as that of the earth, were compressed into a globe equal in size to the earth, the body in question, instead of weighing one pound, would weigh 341908. But as the surface of the sun is 111 times as far from his centre as that of the earth is from its centre, it thence follows that the above weight must be diminished in the ratio of 12321, or of the square of 111, to the square of unity; that is, we must take only the 12321st part of the weight above found, which gives the preceding result, viz. $27\frac{3}{4}$.

By a similar reasoning it will be found, that a body of a pound weight carried to the surface of Jupiter, would weigh $3\frac{1}{10}$ pounds; to that of Saturn $1\frac{7}{9}$ and to that of the moon only 3 ounces.

The masses of Mercury, Venus, and Mars, cannot be ascertained; because no bodies circulate around them, and therefore the problem cannot be solved in regard to them.

PROBLEM XII.

To construct a fountain which shall throw up water by the compression of the air.

Let there be a vessel, a section of which is represented pl. 2 fig. 10, namely composed of a cylindric pedestal or parallelopipedon, crowned with a kind of cup FAED. This pedestal is divided, by a partition NO, into two cavities, the lower one of which must be somewhat smaller than the other.

A tube GH, passing through the partition, reaches nearly to the bottom CB; while another tube LM has its upper orifice near the bottom of the cup, and its lower M near the partition NO. A third tube IK, which, like the first, passes through the bottom of the cup, tapers to a point at the upper end, and with the other reaches nearly to the partition.

When the vessel has been thus constructed, pour water into the upper cavity, through a lateral hole, till it reaches nearly to the orifice L of the tube ML; then carefully stop the lateral hole, and pour water into the cup; this water, flowing into the cavity NB, will compress the air in it, and will force it, in part, to pass through ML into the space above the water in the upper cavity, where it will be more and more condensed, and force the water to spout out through the orifice I, especially if it be some time confined, either by keeping the finger on the orifice I, or by means of a small stopcock, which can be opened when necessary.

REMARKS.—I. This small fountain may be varied different ways. Thus, for example, if the weight of the water which flows through GH into the lower cavity NB, be not sufficient to give the necessary force to the water which issues through I, water might be introduced by means of a syringe, or even air by means of a pair of bel-

lows adapted to the orifice G, and furnished at the nozzle with a stopcock.

Quicksilver might also be poured into it: this fluid would enter it notwithstanding the resistance of the air, and force it to exercise a powerful action on the fluid contained in the upper cavity.

II. This fountain might be constructed in a manner still simpler. Provide a bottle, such as AB, pl. 2 fig. 11, and introduce into it, through the cork, a tube CD, the lower orifice of which reaches nearly to the bottom, while the upper one terminates in a narrow aperture. The communication between the external air and that in the bottle ought to be completely intercepted at A. Let us now suppose that this bottle is three-fourths filled with water; if you breathe with all your force into the tube through the orifice C, the air in the space AEF will be condensed to such a degree, as to press on the surface of the water EF, which will make it issue with impetuosity through the orifice C, and even force it to rise to a considerable height. When the play of the machine has ceased, if any water remains in it, to make it recommence its play, nothing will be necessary but to blow into it again.

PROBLEM XIII.

To construct a vessel, into which if water be poured, the same quantity of wine shall issue from it.

The solution of this problem is a consequence, or rather a simple variation of the preceding. Let us suppose that the small tube IK, pl. 2 fig. 10, is suppressed, and that the cavity AO is filled with wine; if a small cock R be inserted into the machine near the bottom NO, it is evident that when water is poured into the cup FAED, the air, being forced into the upper cavity, will press on the surface of the wine, and oblige it to flow through the cock, until it be in equilibrium with the weight of the atmosphere: if

more water be then poured into the cup FD, nearly as much wine will issue through the cock; so that the water will appear to be converted into wine.

Hence, if it be allowable to make allusion to a celebrated event recorded in the sacred scriptures, were this machine constructed in the form of a wine-jar, it might be called the pitcher of Cana.

PROBLEM XIV.

Method of constructing an hydraulic machine, where a bird drinks up all the water that spouts up through a pipe and falls into a bason.

Let ABDC, pl. 2 fig. 12, be a vessel, divided into two parts by a horizontal partition EF; and let the upper cavity be divided into two parts also by a vertical partition GH. A communication is formed between the upper cavity BF and the lower one EC, by a tube LM, which proceeds from the lower partition, and descends almost to the bottom DC. A similar communication is formed between the lower cavity EC and the upper one AG by the tube IK, which rising from the horizontal partition EF, proceeds nearly to the top AB. A third tube, terminating at the upper extremity in a very small aperture, descends nearly to the partition EF, and passes through the centre of a bason RS, intended to receive the water which issues from it. Near the edge of this bason is a bird with its bill immersed in it; and through the body of the bird passes a bent syphon QP, the aperture of which P is much lower than the aperture Q. Such is the construction of this machine, the use of which is as follows.

Fill the two upper cavities with water through two holes, made for the purpose in the sides of the vessel, and which must be afterwards shut. It may be easily seen that the water in the cavity AG ought not to rise above the orifice K of the pipe KI. If the cock adapted to the pipe

LM be then opened, the water of the upper cavity HF will flow into the lower cavity, where it will compress the air, and make it pass through the pipe KI into the cavity AG; in this cavity it will compress the air which is above it, and the air pressing upon it, will force it to spout up through the pipe NO, from whence it will fall down into the bason.

But at the same time that the water flows from the cavity BG into the lower one, the air will become rarefied in the upper part of that cavity: hence, as the weight of the atmosphere will act on the water, already poured into the bason through the orifice O of the ascending pipe NO, the water will flow through the bent pipe QSP, into the same cavity BG; and this motion, when once established, will continue as long as there is any water in the cavity AG.

PROBLEM XV.

To construct a fountain, which shall throw up water, in consequence of the rarefaction of air dilated by heat.

Construct a cylindric or prismatic vessel, a section of which is represented pl. 2 fig. 12, n°. 2, raised a little on four feet, that a chafing-dish with coals may be placed beneath it. The cavity of this vessel must be divided into two parts by a partition EF, having in it a round hole about an inch in diameter: into this hole is inserted a pipe GH, which rises nearly to the top, and over the top is placed a vessel in the form of a bason, to receive the water furnished by the jet. Another pipe IK passing through the top, into which it is soldered or cemented, descends nearly to the partition EF: this pipe may be made a little wider at the lower extremity, but the upper end ought to be somewhat narrow, that the water may spout up to a greater height. It will be proper to adapt to the upper part of this pipe a small stopcock K, by means

of which the water can be confined till the air is sufficiently rarefied to produce the jet.

When the machine is thus constructed, pour water into the upper cavity till it reaches the orifice H of the tube GH; then place a chafing-dish of burning coals, or a lamp with several wicks, below the bottom of the vessel. By these means the air contained in the lower cavity will be immediately rarefied, and passing through the pipe GH, into the space above the water, contained in the upper cavity, will force it to rise through the orifice I of the pipe IK, and to spout up through the aperture K.

To render the effect more sensible and certain, it will be proper to put a small quantity of water into the lower cavity; for when this water begins to boil, the elastic vapour produced by it, passing into the upper cavity, will exert a much greater pressure on the water, and force it to rise to a more considerable height.

Care however must be taken, if the steam of boiling water be employed, not to heat the machine too much, otherwise the violent expansion of the water might burst it.

PROBLEM XVI.

To measure the degree of the heat of the atmosphere, and of other fluids. History of thermometers, and the method of constructing them.

One of the most ingenious inventions, by which the revival of sound philosophy was distinguished in the beginning of the 17th century, was that of the instrument known under the name of the thermometer, so called because it serves to measure the temperature of bodies, and particularly that of the atmosphere, and of other fluids, into which it can be immersed. This invention is generally ascribed to the Academy del Cimento, which flourished at Florence under the protection of the grand-dukes of

the house of Medici, and which was the first in Europe that applied to experimental philosophy. It is asserted also, that Cornelius Drebbel of Alcmaer in north Holland, who lived at the court of James I. king of England, had a share in this invention. But we shall not here enter into a discussion of this point in the history of Natural Philosophy, as it is foreign to our design *.

The invention of the thermometer is founded on the property which all bodies, and particularly fluids, have of dilating by the heat which pervades them. As spirit of wine possesses this property in an eminent degree, this liquid was employed in preference to any other. A very narrow glass tube, terminating in a bulb of about an inch in diameter, was filled with this liquor, after it had been coloured red by means of tincture of turnsol, or orchilla weed, in order to render it more visible. It may be easily conceived, that the size of the bulb being considerable, compared with that of the tube, as soon as the liquor became in the least dilated, it would be in part forced to pass into the tube: the liquor therefore would be obliged to ascend. On the other hand, when condensed by cold, it would of course descend. It was only necessary to take care, that during very cold weather the liquor should not entirely descend into the bulb; and that during the greatest degree of heat to be measured, it should not entirely escape from it. Towards the lower part, some degrees of temperature were inscribed by estimation: such as *cold*,

* The first description of a thermometer ever published, is that of Solomon de Caux, a French engineer, in his book *Des Forces Mouvantes*, printed in 1624, in folio, but written, as appears, prior to that period, for the dedication to Louis XIII, is dated 1615, and the privilege granted by that monarch is of 1614. The thermometer here alluded to, acts by the dilatation of air confined in a box, which, pressing against water, forces it to rise in a tube. As Drebbel's thermometer was of the same kind, it may be asked whether his invention was prior to that of Solomon de Caux? This is a question which seems difficult to be determined. - *Note of the French censor.*

and a little lower *great cold;* towards the middle *temperate*, and at the top *heat*, and *great heat.*

Such is the construction of that thermometer called the Florentine, which was used for almost a century; and such are those still sold in many country places by itinerant venders, and which are purchased with confidence by the ignorant.

This thermometer, though its form and the greater part of its construction have been retained, is attended with this fault, that it indicates the variations of heat only in a very vague and uncertain manner. By its means we may indeed know that one day has been hotter or colder than another; but that degree of heat or cold cannot be compared with another degree, nor with the heat or cold in another place: besides, the words *heat* and *cold* are merely relative. An inhabitant of the planet Mercury would probably find one of our hottest summers exceedingly cool, and perhaps very cold; while an inhabitant of Saturn, if transported to the frigid zone of our earth during winter, would perhaps find it intolerably hot. We ourselves, at the close of a fine day in summer, experience a sensation of cold, when removed into air much less hot, and *vice versa.*

On this account, attempts have been made to construct thermometers, by which the degrees of heat and cold could be compared to a degree of heat and cold invariable in nature; so that all thermometers constructed according to this principle, though by different artists, in different places and at different times, should correspond with each other, and indicate the same degree when exposed to the same temperature. This was the only method of making experiments that could be of utility.

This was at length accomplished by means of the two following principles, which were discovered by experience.

The first is, that the degree of the temperature of pounded ice, beginning to melt, or of water beginning to freeze, is constantly the same, at all times and in all places.

The second is, that the degree of the temperature of boiling water is also constant. We here speak of fresh water; and we suppose also that the weight of the atmosphere does not vary; for we know that when water is pressed with a greater weight, it requires a degree of heat somewhat greater than when it is less pressed. This is proved by the pneumatic machine, from which if a part of the air be exhausted, water boils at a less degree of heat than when exposed to the open air. Hence arises a sort of paradox, that at the summit of a mountain, the same quantity of heat is not required to boil water as at the bottom of it. But when the gravity of the air is the same, and when the water holds no salt in solution, it begins to boil at the same degree of heat; and when it once attains to that state, it never acquires a greater degree, however long it may be boiled.

These two constant degrees of heat and cold, so easy to be obtained, have therefore appeared to philosophers, very proper for being employed in the construction of thermometers. The simplest method for this purpose is as follows:

Provide a tube, one of the ends of which is blown into a bulb of about an inch in diameter; if the tube be a capillary one, the bulb may be smaller. By a process which we shall describe hereafter, pour quicksilver into the tube, till it rises to the height of a few inches above the bulb; and then immerse the bulb into pounded ice put into a bason. When the mercury ceases to fall, make a mark on the tube, in order that this point may be known; then immerse the thermometer into boiling water, and mark the point where the mercury ceases to rise, which will be that of boiling

water. Nothing then will be necessary but to divide the interval, between these two marks, into any equal number of parts at pleasure, such as 100, for instance, which appear to us to be the most convenient. For this purpose affix the tube to a small piece of board, having a slip of paper cemented to it, and divide the interval between the marks into the number of parts you have chosen: if 0 be inscribed at the point of freezing, and if a few degrees be marked below it, your thermometer will be constructed.

Care however must be taken, to ascertain whether the diameter of the tube is uniform throughout: for it may be easily seen that a tube of unequal calibre, would render the motion of the mercury irregular. For this purpose, introduce a small drop of mercury into the tube, and make it pass from the one end to the other; if it every where occupies the same length, it is evident that no part of the tube is narrower than another; if the drop becomes lengthened or shortened, the tube must be rejected as faulty.

Several of the modern philosophers, with a view to improve the construction of thermometers, have entered into minute details in regard to the increase of volume which mercury and spirit of wine acquire, when they pass from the degree of freezing to that of boiling water; but it appears to us, that as these two terms have been found to be invariable, they might have saved themselves the trouble of entering into these considerations, which tend only to render their processes more difficult.

It now remains that we should describe the method of filling the bulb and tube with the fluid intended to form the thermometer; and which, for reasons to be mentioned hereafter, we shall suppose to be mercury; for this operation is attended with some difficulty, especially when the tube is very small.

The first thing to be attended to, is to clean very well

the inside of the tube; which, if it be not a capillary one, may be done by means of a very dry plug fixed to the end of a wire, and then drawn up and down the tube. If the tube be capillary, it must first be heated, and then the bulb: the air issuing from the latter will expel any dirt that may be adhering to it.

The mercury ought to be exceedingly pure, or revived by means of cinnabar; it must also be boiled, to expel the air which may be diffused through it.

When these preparations have been made, attach to the summit of the tube a small paper funnel; apply the tube to a chafing-dish in such a manner, as to heat it gradually, and then heat the bulb in the same manner, till it cannot be held in the hand without a thick glove. When the thermometer has acquired this degree of heat, if the small funnel above mentioned be filled with heated mercury, in proportion as the glass cools the air will become rarefied, and afford a passage to the mercury into the bulb, till it be in equilibrium with it. Repeat the same operation to introduce a new quantity of mercury, and so on till the tube is full; and then graduate the thermometer, expelling from it, by the means of heat, what is more than necessary to make it reach the highest point marked towards the upper extremity of the tube, when immersed in boiling water. When this point has been fixed, mark it by means of a thread, or by notching the tube with a file, and having suffered the thermometer to cool, immerse it in melting ice, which will give the freezing point.

It may be readily conceived, that if the whole mercury, during this operation, should enter the bulb, it will be necessary to introduce a little more, in order to carry the point of boiling water somewhat higher.

Melt and draw out the upper end of the tube, by applying it to an enameller's lamp, and heat the mercury to such a degree, as to make it ascend near to the summit; then

seal it hermetically at the lamp, and by these means nothing will remain in the upper end of the tube but a quantity of air imperceptible, or exceedingly small.

Then affix the tube to a board, made of some wood which has the property of expanding but a very little in length by heat: fir has this property as well as that of lightness: the bulb must be insulated from the board that the air may surround it more freely, and that it may not be affected by the heat which the wood may acquire.

A question here naturally arises: what kind of liquor is the best, and most convenient for constructing accurate and durable thermometers—Spirit of wine or mercury?

In our opinion, this question is attended with no difficulty; for all philosophers must agree that mercury is the fittest fluid for constructing thermometers. No doubt of its superiority over spirit of wine can be entertained by those who consider:

1st. That spirit of wine, unless well dephlegmated, is not always the same; and who can assert that, in its different states, its progress is always the same, or that its dilatation is not different at the same degree of heat? This point has been determined by experience; and therefore no certain comparison can be made between different spirit of wine thermometers.

2d. If spirit of wine be well dephlegmated, as it then becomes highly spirituous and volatile, is it not to be apprehended that its volume may be gradually diminished? It is indeed true, that to prevent this inconvenience, the tube is hermetically closed at the top; but this precaution will not prevent the most volatile part from being exhaled in the upper part of the tube; and in that case the spirit of wine, becoming less expansible, will remain below the degree at which it ought to be; and the same thing will take place in every state of the spirit of wine, whether it

be employed with water, as is usual, in order to moderate its dilatability.

3d. Spirit of wine boils at a degree of heat less than that of boiling water; consequently it is not proper for examining degrees of heat which are greater; for beyond ebullition the progress of the dilatation of any liquor does not follow the same laws; because after that term it becomes volatilized, or is suddenly reduced into vapour of a volume a thousand times greater.

On the other hand, spirit of wine, when united with water, is susceptible of freezing at a degree of cold not much less than that at which water congeals; and therefore it is very improper for measuring degrees of cold much below that term.

Mercury is attended with none of these defects. This substance, as far as chemists have been able to ascertain, is of an uniform nature when pure; to make it boil requires a degree of heat six times as far distant from zero, or the term 0, as that at which water boils: and it does not freeze but at a degree of cold very far indeed below that of the congelation of water.

Another advantage of mercury, whether employed in thermometers or barometers, is, that while in the act of rising, the small column assumes a convex form at the top, and when it falls a concave form: for this reason, when the summit assumes a convex form, we can say that the mercury is in the act of rising; and when it becomes concave, we may conclude that it begins to fall; which is very convenient for prognosticating heat, and for ascertaining whether it increases, or has become stationary, or has begun to decrease.

PROBLEM XVII.

Description of the most celebrated thermometers, or those

chiefly used: Method of reducing the degrees of one to corresponding degrees of another.

Several thermometers, different in the division of their scale, though constructed on the same principle, are employed in Europe. As the division of the scale is altogether arbitrary, it is necessary that we should point out the method of reducing degrees of the one to corresponding degrees of another.

These thermometers are, that of Fahrenheit, that of Reaumur, that of Celsius, and that of Delisle.

The first of these thermometers is constructed with mercury, and is graduated in a manner which, on the first view, may appear rather whimsical. The freezing point corresponds to the 32d degree; and between this point and that of boiling water there are 180 degrees; so that the heat of boiling water corresponds to the 212th degree. The reason of this division is that Fahrenheit assumed, as the zero of his thermometer, the greatest degree of cold which he could produce by a mixture of snow and spirit of nitre; having then immersed his instrument in melting ice, and afterwards in boiling water, he divided the interval between these two points into 180 degrees, which gave him 32 between the above artificial cold and that of common freezing. Experience has since shown, that it is possible to produce an artificial cold much more intense than that produced by Fahrenheit.

This thermometer is that generally used in England; but it appears that the scale is not the most commodious. It might however be improved by transposing zero to the place of the 32d degree, in which case there would be 180 degrees between the freezing point and that of boiling water; and the degree now marked 0 in this thermometer, would be -32, denoting the degrees below freezing by the negative sign *minus*. Fahrenheit, it appears, was the

first person who employed mercury in the construction of this instrument.

Reaumur's thermometer is generally made with spirit of wine, and is graduated in such a manner, that the degree of melting ice is marked 0, and that which corresponds to boiling water is marked 80; consequently there are 80 degrees between these two points. The scale below 0 is marked 1, 2, 3, 4, &c; and when these degrees are used, the words *below freezing* are added, or for the sake of brevity the sign —.

Delisle's thermometer is much used in the North; and for this reason it is necessary we should make known the manner in which it is divided. Delisle begins his scale at the point of boiling water, and proceeds downwards to the freezing point; between which and that of boiling water there are 150 degrees: 150 degrees of his thermometer correspond therefore to 80 of Reaumur, or 180 of Fahrenheit.

Celsius of Upsal, and Christin of Lyons, sensible of the defects of spirit of wine, and finding the division into 80 degrees inconvenient, endeavoured to remedy these faults, by constructing a thermometer with mercury, and dividing the interval between the freezing point and that of boiling water into 100 degrees. The only difference between this thermometer and that of Reaumur, is, that mercury is used instead of spirit of wine, and that 100 divisions are employed in the same space in which Reaumur employs 80: one degree of the thermometer of Celsius is therefore equal to $\frac{4}{5}$ of a degree of that of Reaumur; consequently, to convert the degrees of Celsius's thermometer to corresponding degrees of Reaumur, multiply by 4 and divide by 5: to convert Reaumur's degrees to those of Celsius, a contrary operation must be employed. To convert the degrees of Celsius's thermometer to those of Fahrenheit's,

multiply by 9, then divide by 5, and to the product add 32. To convert Fahrenheit's degrees to those of Celsius, subtract 32 from the number of degrees proposed, and having multiplied the remainder by 5, divide the product by 9.

To convert degrees of Fahrenheit into degrees of Reaumur, the following process must be employed: if the degrees of Fahrenheit are above 32, subtract 32 from them, then multiply the remainder by 4, and divide the product by 9, the quotient will be the corresponding degree of Reaumur's division. Let the proposed degree of Fahrenheit, for example, be 149: if 32 be subtracted from this number, the remainder will be 117, which multiplied by 4, gives for product 468; and if this product be divided by 9, we shall have for quotient 52, which is the corresponding degree of Reaumur's thermometer.

If the degree of Fahrenheit be between 0 and 32, it must be subtracted from 32; then multiply the remainder by 4, and divide the product by 9: the quotient will be the corresponding degree of Reaumur's thermometer. In this manner it will be found, that 12 degrees of Fahrenheit, correspond to $8\frac{8}{9}$ degrees of Reaumur, below freezing.

Lastly, when the proposed degree is below 0, add it to 32, and then proceed as above directed: the quotient will be the corresponding degree of Reaumur's thermometer. Thus, it will be found that the 45th degree of Fahrenheit, below 0, corresponds to $34\frac{2}{9}$ degrees below 0, of Reaumur.

It may here be readily seen, that to convert degrees of Reaumur's scale to the corresponding degrees of Fahrenheit's, the reverse of this operation must be performed.

In regard to Delisle's thermometer; it is evident, from its construction, that the 150th degree in its scale, corresponds to the zero of Reaumur's scale. If the proposed degree of Delisle's thermometer then be less than 150, it must be subtracted from 150: if you then multiply by 8,

and divide by 15, the quotient will be the corresponding degree of Reaumur, above freezing.

Let the proposed degree of Delisle's thermometer, for example, be 120: if this number be subtracted from 150, the remainder will be 30; then say, as 150 to 80, or as 15 to 8, so is 30 to a fourth term, which will be 16 = the degree of Reaumur's thermometer, above 0 or the freezing point.

If the degree of Delisle's thermometer exceeds 150, as if it be 190, for example, subtract 150 from it, which will leave for remainder 40; then make use of this proportion, as 15 is to 8, so is 40 to $21\frac{1}{3}$, which will be the degree of Reaumur's thermometer, below 0, corresponding to the 190th degree of Delisle's thermometer.

As it will be easy to perform the reverse of this operation, in order to convert the degrees of Reaumur's thermometer into those of Delisle's, more examples are needless.

It is certainly much to be wished that all philosophers would agree to employ only one kind of thermometer, that is to say, constructed in the same manner with mercury, and having the same scale. In regard to the latter, there can be no doubt that the division of 100 parts, between the freezing point and that of boiling water, would be preferable to any other, as decimal divisions are attended with many advantages in regard to facility of calculation *.

PROBLEM XVIII.

Construction of another kind of thermometer, which measures heat by the dilatation of a bar of metal.

The property which all metals have of dilating by heat, serves as a principle for the construction of another ther-

* The French have adopted this division, and the thermometer divided in this manner is called the centigrade.

mometer, exceedingly useful, as much greater degrees of heat can be measured by it than by other thermometers; for a spirit of wine thermometer cannot measure a degree of heat greater than that acquired by spirit of wine in a state of ebullition; and a mercurial thermometer cannot measure any degree of heat greater than that of boiling mercury. It was perhaps for this reason that Newton employed, in his thermometer, linseed oil; for it is well known that fat oils, before they are brought to ebullition, require a degree of heat much greater than that which fuses the greater part of the metals and semi-metals, such as lead, tin, bismuth, &c.

Muschenbroeck is the inventor of this new kind of thermometer, called also *Pyrometer*. Its construction is as follows.

If we suppose a small bar of metal, 12 or 15 inches in length, made fast at one of its extremities, it is evident, that if it be dilated by heat, it will become lengthened, and its other extremity will be pushed forwards. If this extremity then be affixed to the end of a lever, the other end of which is furnished with a pinion adapted to a wheel, and if this wheel move a second pinion, the latter a third, and so on, it will be evident that, by multiplying wheels and pinions in this manner, the last one will have a very sensible motion; so that the moveable extremity of the small bar cannot pass over the hundredth or thousandth part of a line, without a point of the circumference of the last wheel passing over several inches. If this circumference then have teeth fitted into a pinion, to which an index is affixed, this index will make several revolutions, when the dilatation of the bar amounts only to a quantity altogether insensible. The portions of this revolution then may be measured on a dial-plate, divided into equal parts; and by means of the ratio which the wheels bear to the pinions, the absolute quantity which a certain degree of

heat may have made the small bar to dilate, can be ascertained; or, by the dilatation of the bar, the degree of heat which has been applied to it may be determined.

Such is the construction of Muschenbroeck's pyrometer. It is necessary to observe, that a small cup is adapted to the machine, in order to receive the liquid or fused matters, subjected to experiment, and in which the bar to be tried is immersed.

When it is required to measure, by this instrument, a considerable degree of heat, such as that of boiling oil or fused metal, fill the cup with the matter to be tried, and immerse the bar of iron into it. The dilatation of the bar, indicated by the turning of the index, will point out the degree of heat it has assumed, and which must necessarily be equal to that of the matter into which it is immersed.

This machine serves to determine the ratio of the dilatation of metals; for by substituting, in the room of the pyrometric bar, other metallic bars of the same length, and then exposing them to an equal degree of heat, the ratios of their dilatation will be shown by the motion of the index.

A TABLE *of the different degrees of heat at which different matters begin to melt, to freeze, or to enter into ebullition, according to the thermometers of Fahrenheit, Reaumur, and Celsius.*

Names of the Matters.	Degrees of Fahrenheit.	Degrees of Reaumur.	Degrees of Celsius.
Mercury congeals	— 39	— 31$\frac{1}{2}$	— 39$\frac{1}{8}$
Mercury boils	708	300	375
Water freezes	32	0	0
Water boils	212	80	100
Rectified spirit of wine freezes	— 33	— 29	— 36
The same boils	175	63$\frac{1}{2}$	79
Brandy consisting of equal parts spirit and water freezes	— 7	— 17$\frac{1}{3}$	— 21$\frac{2}{3}$
The same boils	190	70	87$\frac{1}{2}$
Water saturated with marine salt boils	218	82$\frac{2}{9}$	103$\frac{1}{3}$
Lixivium of wood ashes boils	240	92$\frac{4}{9}$	114
Burgundy, Bourdeaux, &c, wine freeze	20	— 5$\frac{3}{5}$	— 7$\frac{1}{4}$
Spirit of nitre freezes	— 40	— 23	— 40
The same boils	242	93$\frac{1}{3}$	116
Wax melts	142	49$\frac{7}{9}$	62$\frac{1}{4}$
Butter melts	80 to 90	21 to 26	26 to 32
Oil of turpentine begins to boil	560	234	292
Olive oil becomes fixed	43	5	6$\frac{1}{4}$
Rape-seed oil boils and is ready to inflame	714	298	372
Tin fused	408	167	309
Lead fused	540	226	282
Bismuth ditto	460	190	238
Regulus of antimony ditto	805	344	430

TABLE *of the different degrees of heat or cold observed in various parts of the earth, or in certain circumstances, or in consequence of certain operations, according to Reaumur's thermometer.*

	Degrees.
Constant heat of the vaults below the observatory of Paris	$9\frac{1}{4}$
Heat at which chickens are hatched	35
. . . at which silk-worms are hatched	19
. . . for an orangery	15
. . . for pine-apples	18
. . . for the chamber of a sick person	17
. . . for a stove	12
. . . of the human skin	29 to 30
. . . of the interior of the human body	31
Fever heat	32 to 40
Heat observed at Paris in 1753	$30\frac{1}{2}$
. . . . at Senegal	37
. . . . in Syria in 1736	35
. . . . at Martinico	32
Cold observed at Paris in 1766	— $9\frac{3}{4}$
. . . . in 1740	— $10\frac{1}{2}$
. . . . in 1754	— 12
. . . . in 1767	— 13
. . . . in 1768	— $14\frac{1}{2}$
. . . . in 1709	— $15\frac{1}{2}$
. . . . in 1776	— $16\frac{3}{4}$
. . . . at Petersburg December 1759	— $33\frac{1}{3}$
. . . . December 1772	— 50
. . . . at Torneo in 1737	— 37
. . . . at Quebec	— 37
. . . . at Upsal in 1733	— 40
. . . . at Kiringa in Siberia in 1738 (See *Flora Siberica*)	— 70
Artificial cold with spirit of nitre and snow cooled to 33 degrees	— 170

TABLE *of the ratio of the dilatation of metals by heat, according to Mr. Ellicot.*

Names of Metals.	Respective Dilatation.
Gold	73
Silver	103
Copper	89
Similor	95
Iron	60
Steel	56
Lead	149
Tin	148

OBSERVATIONS ON THE PRECEDING TABLES.

I. The first observation we shall here make, is on the congelation of mercury by an extraordinary degree of cold. This singular experiment was made, for the first time, at Petersburg in the month of December 1759, and deserves that we should here give a particular account of it.

The cold having become very intense in that city, in the month of December 1759, Mr. Braun embraced that opportunity of making some experiments on the artificial cold that could be produced, assisted by its means. He put into a glass vessel snow already cooled to 208 degrees of Delisle's thermometer, or 31 degrees of Reaumur, and having cooled to the same degree good fuming spirit of nitre, he poured it upon the snow. He then immersed in the mixture the bulb of a thermometer, so constructed that the scale of it extended about 6000 degrees, both above and below zero, which in Delisle's thermometer is the point of boiling water, and saw with astonishment the mercury rapidly descend to the 470th degree below that term. The mercury having then stopped, Mr. Braun shook the thermometer, and found that the mercury had

no motion. He broke the bulb, and found that the mercury was completely frozen. This experiment was repeated either the same day, or on the 26th of December, when the natural cold was still more intense, and the mercury fell to the 212th degree of Delisle's thermometer, or the 33d of Reaumur. Several of the Academicians of Petersburg were present at the latter experiment, and confirmed the truth of it. The small ball of congealed mercury was hammered, and it appeared to have the ductility of lead.

One thing very singular, and which Mr. Braun remarks with astonishment, is, that in several of these experiments the mercury fell with moderate velocity from the point of the temperature of the air to that of 470 degrees below zero; but when it reached that term it fell at once below the 600th degree, without the bulb of the thermometer being broken.

This phenomenon, in our opinion, is nearly the inverse of that which takes place in the congelation of water. It is well known that in proportion as water cools, it diminishes in volume; but when it reaches the degree of congelation, it suddenly increases in volume, so that if a thermometer were constructed with pure water, it is probable the water would first fall, and then suddenly rise, or burst the ball of the thermometer. This is an effect of the new arrangement of the parts which takes place, with a force almost irresistible, at the moment when they are all in contact.

But there is reason to think, that in mercury the contrary is the case; that is to say, when cooled to such a degree that its component particles are almost in contact, they suddenly arrange themselves in a certain form by their mutual attraction, and this form is apparently such, that in this disposition they must occupy less volume, as those of water occupy more.

But, however this may be, it is confirmed by the experiment of Mr. Braun, that mercury is only a metal kept in a state of fusion by a degree of heat much less than that which freezes water, and a multitude of other liquors. We must even remove it from the class of semi-metals, and rank it among the number of real metals.

We find also, in this experiment, the reason why mercury is the most volatile of the metals. Since the degree of heat necessary to keep it in fusion, is so far below that which melts ice, it needs excite no astonishment that at the 300th degree of Reaumur's thermometer it begins to be volatilized; for this degree is about the 500th above that which keeps it in a state of fusion: in regard to it this degree is almost the same as the 600th would be to lead, or the 1200th to copper, &c.

II. Another remark is, that the degree of water' beginning to freeze is indeed fixed; but the case is not entirely the same with that of boiling water. Is has been found that the more water is charged with the weight of the atmosphere, the greater is the degree of heat necessary to make it boil. This was remarked by M. le Mounier, who found at the summit of the Canigou that boiling water raised the thermometer only to the 78th degree. This has been since proved by other philosophers, such as M. de Secondat, the son of the celebrated Montesquieu, on the Pic du Midi, one of the highest mountains of the Pyrenées, and by Mr. Deluc on a mountain still higher. Water has also been made to boil under the receiver of an air pump, at a degree much below the 80th of the thermometer: this effect may be produced by partly evacuating the air.

It is therefore necessary that this degree of the thermometer should be fixed, taking into consideration the height of the barometer; and in rectified and comparative thermometers, of which we have heard, the 80th degree is that which indicates boiling water when the height of the ba-

rometer is 27 inches, Paris measure, or 28·8 English inches: this is what we ought to understand by the degree of boiling water.

It has been found also, that the thinnest liquors boil at a degree of heat less than water; but that fat oils require a much greater degree.

III. We have rectified, according to the observations of Deluc, or observations made at his request, the temperature of the vaults of the observatory at Paris, which is not 10 as commonly said, but 9¼ at most. We have rectified also by the observations of M. Braun, the degree of boiling mercury which is generally placed at the 600th degree of Fahrenheit, but which, according to that philosopher, is the 708th or 709th.

IV. In the table of the dilatation of metals, it is seen that steel is that which dilates the least by heat; the next is iron, and the next to that is gold. Lead and tin dilate the most. It appears also by this table, that the dilatability does not follow the ratio of the specific gravities, nor that of the ductility, nor of the strength of these metals: there are even irregularities in their dilatations, on which account it is to be wished that a greater number of experiments were made on this subject, and in a more correct manner.

Remark.—It is rather matter of surprise, that M. Montucla has taken no notice of the accounts of the freezing and fixing of mercury, in the Philos. Trans. for the year 1783, especially as the errors of M. Braun concerning this matter are there corrected, and the degree of cold at which it freezes is ascertained by many different persons, both by natural cold, and by artificial mixtures, with perfect satisfaction: It is there proved, that the degree of cold at which mercury freezes, is—39 of Fahrenheit, or 39° below 0 in that scale. It is also shown, that the extraordinary degree of depression of thermometers accompanying frozen mercury, which deceived M. Braun, and some

other persons, is owing to the sudden contraction of mercury in the act of freezing, and after it; contrary to the nature of water, which expands and enlarges in the same circumstances. Hence it happens that congealed mercury, becoming more dense and compact, sinks in fluid mercury, while common ice, or congealed water, floats in that fluid.

PROBLEM XIX.

What is the cause of the intense and almost continual cold experienced on the tops of high mountains, and even of those situated in the torrid zone; while it is hot in the neighbouring plains or valleys?

The cold experienced on high mountains, while the neighbouring plains are exposed to the most violent heat, is a phenomenon which has long excited the attention of philosophers. It is now known that one of the hottest climates in the world is the coast of Peru, and yet those who gradually ascend the Cordilleras from it, observe that the heat progressively decreases, so that when they have got to the valley of Quito, at the height of about 1400 toises above the level of the sea, the thermometer, in the course of the whole year, scarcely rises 13 or 14 degrees above zero. If they ascend still higher, this temperature is succeeded by a severe winter, and when they get to the perpendicular height of about 2400 toises, they meet with nothing, even under the equinoctial line, but eternal ice.

Some philosophers have asked how this is possible? In proportion as they rise above the surface of the earth, they approach the sun, consequently his rays ought to be warmer; and yet they experience the contrary. Some have thence concluded that the rays of the sun are not the principle of the heat which we experience; for if they are, say they, how comes it that they have less activity

exactly in the place where they ought to have more? This paradox we shall endeavour to explain.

It must first be observed, that when people ascend to the height of some thousands of yards above the surface of the earth, it is wrong for them to conclude that the rays of the sun ought to have more activity there than at the surface. This difference would be insensible, even if they should ascend to a height equal to the earth's semi-diameter, or some thousands of miles; for the sun being at the distance of 22000 semi-diameters of the earth, and as the heat of the sun's rays increases in the inverse ratio of the squares of the distances, the direct heat of the sun at the height of a semi-diameter of the earth, will be to that experienced at the surface, as the square of 21999 to the square of 21998; a ratio which will be found to be that of 10999 to 10998, or of 11000 to 10999; so that the heat would be only one 11000th part less at the surface than at the distance of the earth's semi-diameter above it, a difference quite insensible. What then can be the difference at the height of four or five thousand feet above the surface of the earth? certainly nothing, and therefore no attention ought to be paid to it.

But there are very sensible physical causes, in consequence of which bodies are less susceptible of heat, and while on those elevated parts of the earth retain it a shorter time than when they are nearer the surface. It is certain that the heat which we experience at the surface of the earth is not merely the effect of the direct heat of the sun, but of several causes united.

These causes are, 1st, the mass of the heated bodies, which retain longer the heat they have received, according as they are denser and more voluminous: hence the terrestrial bodies retain, even in a great measure throughout the night, the heat communicated to them during a fine summer's day. The day after this they receive an-

other accession of heat by the presence of the sun; and so on in succession.

2d. The air being more dense in the plains and valleys, it retains a greater portion of the heat it receives in the day-time, and prevents the dissipation of the heat communicated to the earth. For this reason, the heat continually increases in the lower grounds, as the sun rises above the horizon; but on the summits of the mountains the case is not the same.

In the first place, the air in those high regions is much rarer than at the surface of the earth. No sooner is the sun sunk below the horizon, than it loses the heat it received in the course of the day; for every person must have observed, that a dense body, such as a piece of money, retains heat longer than a body of little density, such as a bit of cloth. If you approach a large fire, and stand some time before it, you will find the money in your pocket burning hot; if you retire, it will be in this state for a long time, while your clothes will retain only a common degree of heat. Hence, the small quantity of heat which the thin air of the mountains has received in the course of a summer's day, is soon dissipated; it is not accumulated there as in the lower regions, where the contact also of dense terrestrial bodies, violently heated, contributes to maintain it in that state. In the second place, the exceedingly high insulated peaks of these mountains are only small masses, when compared with the whole of the terrestrial bodies in the plains and the valleys. If they are heated to a certain point, the heat they have received is speedily evaporated; and this evaporation is promoted by the coolness of the surrounding air, which is lowered to the temperature of ice, almost as soon as the sun has set.

Hence it may be easily conceived that the air, which surrounds high mountains, acquires only in a very transient manner a certain degree of heat; that it is almost always

below even the temperature of ice; that on this account all the aqueous meteors there formed, are converted into snow and ice; that when a certain mass is once formed, it will oppose the introduction of heat, either into the surrounding air, or into the parts which it covers; and this new obstacle will tend to increase the cold and the mass of the ice. In this manner have been formed those accumulated masses of snow and ice which cover the summits of the Cordilleras, as well as some parts of the Alps and the Appenines; in short, all those mountains of the universe whose height exceeds a certain limit, which in the torrid zone is about 2400 toises perpendicular elevation above the level of the sea.

We must here remark that this height is less as the latitude is greater; thus, in the torid zone, you must ascend to the height of 2400 or 2500 toises to arrive at those regions of perpetual ice; but in the temperate zone, for example, these eternal glaciers will be met with at the height of 14 or 1500 toises. The commencement of those found in Swisserland, according to the measurement of Mr. Deluc, is at the height of 1500 toises above the level of the Mediterranean; and on proceeding farther north they will be found nearer the level of the sea. The glaciers of Norway are certainly less elevated than those of Swisserland. In short, in the frigid zone that region of continual ice is at the surface of the earth. Hence it happens that in those regions the ice, as is well known, never melts. Both the arctic and antarctic poles are surrounded, to the distance of several hundred of leagues, with circular bands of ice; which, according to every probability, exclude all hope of ships being ever able to traverse the frozen ocean, in order to proceed through the seas of China and Japan to the passage known to exist between Asia and America.

PROBLEM XX.

Of the attenuation of which some matters are susceptible: Calculation of the length to which an ingot of silver may be wire-drawn and of the thickness of gilding.

We shall not here examine the question which has so much engaged the attention of philosophers, whether matter be divisible or not ad infinitum. To resolve this question, it would be necessary to be acquainted with the ultimate moleculæ or elements of bodies, which in all probability are placed beyond our reach. But nature and art present to us some instances of the attenuation of matter, which if they do not prove its divisibility ad infinitum, prove at least that the boundaries of this division are removed beyond what the imagination can conceive.

The ductility of silver and gold supplies us with two of those examples furnished by art. An ounce of gold is a cube of 5¼ lines on each side; so that one of its faces will consequently cover about 27 square lines. This cube, a gold-beater reduces into leaves, which all together, would cover 146 square feet. But 27 square lines are contained 111980 times in 146 square feet; consequently the thickness of this gold leaf is the 111980th part of 5¼ lines, or the 21534th part of a line.

But we can go still farther: for this attenuation is nothing in comparison of the following.

A cylindric ingot of silver, weighing 45 marcs, about 22 inches in length, and 15 in breadth, is covered with six ounces of gold reduced to gold-leaf. The thickness of the gold in this state, called gilding, is about the 15th part of a line. But only one ounce of gold may be employed; and in this case the thickness of the gilding will be only the 90th part of a line.

The ingot thus gilt is made to pass through several holes in succession, each smaller than the other, till it is

reduced to a wire of the thickness of a hair. M. Reaumur took a wire of gilt silver, drawn out in this manner, and having weighed half a gros of it, with the greatest nicety, measured its length, which he found to be 202 feet: whence it is easy to conclude that the gros must have been 404 feet in length; the ounce 2232, the marc 23856, and the 45 marcs 1163520 or 96 leagues of 2000 toises each. Here then we have an ingot of silver, 22 inches in length, drawn out in such a manner, as to form a wire of 96 leagues in length.

Nay more, this gilt wire is made to pass between two rollers of polished steel, to flatten it, and reduce it to a thin plate. This operation, by rendering it $\frac{1}{8}$ of a line in breadth, lengthens it a seventh part more at least; so that the wire by these means is converted into a thin plate 110 leagues in length, with the thickness of the 256th part of a line. In regard to the gold, it will be found that its thickness is only the 59000th part, and even the 60000th part of a line.

Thus, if we suppose the ingot of silver to have been gilt with two ounces of gold, its thickness would be the 175000th part of a line; and supposing only one ounce of gold, the thickness would be the 350000th. But as there are some places of the plate unequally gilt, if we suppose that these are a half less than the rest, it will be found, that the thickness of the latter will be only one 525000th of a line.

Lastly, it is well known that this plate may be made to pass a second time under the steel rollers, bringing them nearer to each other, in such a manner as to render its breadth double; hence it follows that in the latter state there are parts of the gilding where its thickness is only the 1000000th part of a line; which is in the same proportion as a line is to the length of 1200 toises, or half a league.

It is however certain that these gold particles have mutual adhesion and continuity; for if this silver wire be immersed in aquafortis, the silver will be dissolved and the gold will remain like a small hollow tube. Lastly, if the gilding be viewed through a microscope, no trace of discontinuity will be observed.

As the ductility of gold is far greater than that of silver, a much longer wire might be made with an ingot of gold of the same weight. But can we believe what is related by Muschenbroek on this subject? This philosopher says, that an artist of Augsbourg made a gold wire, weighing only a grain, which however was 500 feet in length. He could therefore have made a gold wire a league in length, and weighing only a dram, or the third of a gros; a wire 24 leagues in length would have weighed only one ounce; and with a pound of gold he could have made a wire 192 leagues in length. A wire of this size, capable of encompassing the globe of the earth, would have weighed only about 50 pounds.

But we can show that a thread, the work of an insect, surpasses in fineness the wire ascribed to the artist of Augsbourg. It has been observed that a single thread of silk, 360 feet in length, weighs a grain; 24 grains therefore will give 1440 toises, and 36 grains a league of 2160 toises: an ounce of this thread will extend 16 leagues, and a pound 128: in short, a thread of this kind capable of encompasing the globe of the earth, would weigh no more than 70 marcs, or 35 pounds. We shall here add, that the thread of a spider's web, which is much finer and lighter than the thread of a silk-worm, of the same length as the above, would weigh only two marcs, or one pound.

PROBLEM XXI.

Continuation of the same subject: Division of matter in the solution of bodies, and in odours and light.

But new subjects of admiration present themselves to us in the prodigious smallness of some parts of matter: these we shall here add on account of their affinity.

Metallic solutions afford the first example. Dissolve a grain of copper in a sufficient quantity of volatile alkali; and you will obtain a liquor of a blue colour. If you pour this solution into three pints of water, the whole water will be sensibly coloured blue. But three French pints make 144 cubic inches; and as each inch in length may be divided into lines, then into tenths of a line, visible to the eye, it will be found, that in these 144 cubic inches, there are 248832000 of such parts, every one of which is coloured blue. A grain of copper is divided then, by these means, into at least 248832000 parts. But we shall go still farther: each of these parts may be seen by a microscope, that magnifies objects 100 times in length, consequently 10000 times in surface; and every one of them will be found to be coloured: if we therefore multiply the above number by 10000, or add to it four cyphers, we shall have a grain of copper divided into 2488320000000 parts, visible to the eye, at least when assisted by the microscope.

Let us now proceed to odours. It is said that a grain of musk is capable of perfuming, for several years, a chamber 12 feet in every direction, without sustaining any sensible diminution in its volume, or its weight. But a space such as the above contains 1728 cubic feet, each of which contains 1728 cubic inches, and each of these 1728 cubic lines; so that the number of cubic lines is the third power of 1728. It is probable, that every one of these cubic lines contains some of the odorous particles: the air of the chamber may in the course of several years be renewed 1000 times; and the grain of musk, without sensible alteration, may furnish new odorous particles. In calculating the tenuity of each of these, the imagination is lost.

However, notwithstanding the tenuity of these odorous particles, they do not pass through glass and metals; and there are certain *effluvia* which penetrate them; such as those of luminous bodies or light, magnetism, and electricity. How great then must be the tenuity of the particles of which these consist! But we shall confine our observations to light.

If those particles, the emission of which constitutes light, were not of a smallness almost infinite, there is no body which could resist the action of the weakest light; for their multitude, and the rapidity with which they proceed from the luminous body, are such, that without this prodigious tenuity light would break to pieces every body on which it might fall, instead of exciting in it that gentle vibration, that insensible tremulous motion, in which heat consists, when it has only the density of the light of the sun.

Light, indeed, in a second passes over 128880 leagues, or 257760000 toises; consequently, if a particle of light were only equal to the 257760000th part of a grain of lead, a line in diameter, it would make on our organs the same impression as a similar grain of lead impelled with the velocity of a toise per second. There is no doubt that such an impression would be very sensible to the delicate parts of our bodies. But what would it be if millions of millions of such globules should strike against it, and be followed at an interval of time infinitely small by a like quantity of others, as is the case when our body is exposed to the light! No human being could resist it.

The tenuity of a particle of light then is still far below that which we have assigned to it as its first limits. Let us endeavour to determine another, that may approach nearer to the truth.

The density of the sun's light, such as it is when it reaches the earth, in our climates, is of such a nature, that if diffused throughout a space 250000 times greater, it would have a splendour equal to that of the full moon.

It is probable that the latter, diffused in the like manner, would be equal, at least, to that of a glow-worm, which enlightens an object at the distance of 10 feet; consequently the latter will be found by calculation to be 62500000000 times weaker. It is besides very probable, that in the pupil of the eye, which at that distance beholds the light of the glow-worm, there is no part which is not itself sensibly enlightened: let us suppose it to be a square line of surface, and that this square line is divided into 10000 sensible parts; every moment therefore there are 10000 globules of light, which reach the retina, united in one imperceptible point, and with the velocity of 257760000 toises per second, without producing however a sensible impression, and even scarcely the perception of light.

If we suppose the same quantity of globules of light thrown by the weakest light on a square line of surface, it will be found that in a line square of the sun's light, there are 625000000000000, and in an inch 90000000000000000. This quantity of globules, moved with the velocity of 257760000 toises per second, and renewed perhaps a thousand times in that interval, would produce however in the palm of the hand but a slight sensation of heat; and hence there is reason to conclude, that 900 thousand millions of millions of these particles, moved with the above velocity, make less impression than the shock of a leaden ball, a line in diameter, which falls from the height of three feet. And hence arises this new consequence, that if we suppose the particles of light to have the same density as lead, each of them compared with a ball of lead a line in diameter, is in a less ratio than a 257760000th, by 90000000000000000 or a 231984000000000000000000th part of unity.

Such then, at least, is the tenuity of the particles of light; and by other reasoning perhaps we might prove that it is still much rarer; so that in all probability the

above ratio must be reduced to that of unity to a comparative number of 30 or 35 figures. But we shall confine ourselves to what has been already said, because it is sufficient for our purpose, and to show, as we have done elsewhere, that the sun for several successive ages, may furnish, without any sensible diminution, sufficient matter for the emission of the light which proceeds from him; and this may serve to answer an objection which has been made to the Newtonian theory of light.

PROBLEM XXII.

What velocity ought to be given to a cannon bullet, in a horizontal direction, to prevent it from falling to the earth, and to make it circulate around it like a planet, supposing the resistance of the air to be destroyed?

If a cannon bullet be fired off in a horizontal direction, from the top of a mountain, it will fall to the earth, as is well known, at a certain distance. If we now suppose that the velocity communicated to this bullet is more and more increased, it will fall at a greater and greater distance; for the parabola, or rather ellipsis, it describes, will be broader and broader. We may therefore conceive the velocity to be so great, that the bullet shall fall to the earth at the point diametrically opposite to that from which it was fired. In this case, if the velocity were increased ever so little, the bullet would not touch the earth, but would return to the point from which it set out; describing a line similar to that which it before described. It would then continually move in an elliptical line, around the earth, and really be a small planet, performing its revolution around it.

The question then is, to find what would be the periodical time of this revolution; for by knowing this time, we could easily find the velocity of the small planet, or that with which the bullet set out; because nothing would be

necessary but to divide the space passed over, which in this case is nearly the circumference of the earth, by the time employed in passing over it.

The solution of this problem may be easily deduced from the celebrated rule of Kepler; for if we suppose our small planet in motion, it must, compared with the moon, perform its revolutions in such a manner, that the squares of the periodical times shall be as the cubes of the distances. But the mean distance of the moon from the earth is 60 semi-diameters, and that of the small planet will be equal to the earth's radius, or 1 semi-diameter. We shall consequently have this ratio, as the cube of 60 or 216000, is to 1, so is the square of the periodical time of the moon, to the square of the periodical time of the small planet. But the periodical time of the moon is 27 days 8 hours, or 656 hours, the square of which is 430336; if we then say, as 216000 is to 1, so is 430336 to a fourth term; we shall have for this fourth term, $\frac{430336}{216000}$, or in decimals 1·9923; the square root of which 1·41, will express the number of hours employed by the small planet in its revolution. But 1·41 in hours and minutes is equal to $1^h\ 24^m\ 36^s$. The small planet, therefore, would perform its revolution in that time; which, supposing a great circle of the earth to be 24000 miles, gives nearly 282 miles per minute, or 4·7 miles per second.

If a velocity greater than the above, but less than $149\frac{1}{7}$ leagues, were given to this body, it would describe an ellipsis, the perigeum of which would be in the point of departure. If the velocity of the projection were $149\frac{1}{7}$ leagues per minute, or greater, the body would not return to the earth; for in the first case it would describe a parabola, the summit of which would be in the point of projection, and in the second it would describe an hyperbola.

PROBLEM XXIII.

Examination of a singular opinion respecting the moon and the other planets.

It has been said, and the singularity of the conjecture has given it some importance, that the moon may be nothing else than a comet, which in approaching to or receding from the sun, and passing at the proper distance from the earth, may have been diverted from its course, and thus have become that secondary planet which accompanies our earth. For, if we suppose that such a comet, having only the projected motion necessary for describing a circle around the earth, at the distance of 60 semi-diameters from its centre, really passed at that distance from our globe, and in a plane inclined to its orbit, it must necessarily, say some philosophers, have become our moon.

This conjecture is supported by some remarks which seem to give it a certain degree of probability. The moon, say they, when viewed through a telescope, presents the appearance of a body which has been torrefied; the cavities interspersed over its surface seem to be fissures, occasioned by the intense heat which caused the moisture it contained to escape in vapours; and they add, that no appearance of humidity now remains in the moon, since it has no atmosphere. All this agrees exceedingly well with a comet, which has passed very near the sun.

It is also to be observed, say they, that the largest planets, such as Jupiter and Saturn, have several satellites; for as their attraction extended much farther than that of the earth, they had a far greater power over the comets which passed in their neighbourhood, the motion of these comets having been besides lessened in consequence of their distance from the sun. The small planets, such as Mercury, Venus, and Mars, have no satellites, on account

of the smallness of their size, and the velocity with which comets pass them, in advancing towards, or receding from the sun.

These ideas are ingenious; but this assertion or conjecture, when examined according to the principles of geometry, cannot be maintained.

It is found, indeed, by calculation, that whatever may be the position or magnitude of the orbit of a comet, it cannot, when it passes near the orbit of the earth, have the velocity necessary to make it become a satellite to it, whatever may be the proximity at which it passes; for it can be demonstrated, that every comet, when it approaches the sun within a distance equal to that of the earth, has at that moment a velocity in its orbit, which is to that of the earth, as $\sqrt{2}$ is to 1, or as 1414 to 1000. But this velocity is far greater than that of the moon in her orbit, and even greater than that of a planet which should circulate almost at the surface of the earth, as the following calculation will show.

The earth in about 365 days passes over an orbit of 597 millions of miles in circumference: its velocity then in its orbit is such, that it passes over in a day 1635616 miles; in an hour 68150; and in a minute 1136; therefore, if we multiply the last number by $\frac{1414}{1000}$, we shall have nearly 1606 miles for the space which every comet, when it arrives at the distance of the earth from the sun, necessarily passes over in a minute.

Let us now examine that of the moon in her orbit. The mean diameter of the moon's orbit is about 60 times the earth's diameter; consequently its circumference will be 188 of these diameters; which, estimating the earth's diameter at 8000 miles, gives for the circumference of the lunar orbit 1504000 miles. This space the moon passes over in 27 days 8 hours, wanting a few minutes; or $27\frac{1}{3}$ days: the moon therefore in her orbit passes over in a day

55024 miles; in an hour 2293, and in a minute 38. Hence it is evident, that if a comet should pass at a distance from the earth equal to that of the moon, which the comet transformed into our satellite might do, it could have a velocity of no more than 38 or 40 miles per minute, instead of 1606, which every comet necessarily has at that distance from the sun. The moon then could not be a comet, which passing too near the earth was, as we may say, subdued and carried away by it.

Let us now see whether the comet in question, by passing much nearer the earth, and even close to its surface, could be attracted by it. We shall find, by a similar calculation, that it could not circulate around the earth; for we have already seen that a body, to circulate round our globe near its surface, would require a velocity of almost 300 miles per minute. But this is far below the velocity which a comet passing very near the earth would necessarily have; for if a body should be projected from the summit of a mountain, towards the East or West, with the velocity of 1600 miles per minute, it would recede from the earth without ever returning to it, that velocity being much greater than is necessary to make it describe around the earth any ellipsis whatever, or even a parabola.

Here then the earth, and no doubt Mars, is excluded from the privilege of ever being able to obtain a satellite in that manner, and this will hold good much more in regard to Venus and Mercury. But is this the case with Jupiter and Saturn? We shall examine this question also, by employing the same kind of calculations.

The velocity of Jupiter's revolution around the sun, is 494 miles per minute; consequently the velocity of every comet advancing to, or receding from the sun, when at the same distance as Jupiter from that luminary, will be about 700 miles, in the same time. It is found that the velocity of the first satellite of Jupiter, in its orbit, is 37366 miles

per hour, or 622 per minute: the velocity then of every comet which should pass Jupiter at the distance of his first satellite, would necessarily be rather more considerable, being about a seventh part more. Hence it follows, that neither the first satellite nor any of the rest was originally a comet, which this large planet appropriated to itself; for the other satellites have a velocity still less than that of the first.

It now remains to determine whether a comet, in passing near Jupiter, could be stopped by it. This indeed does not appear to be absolutely impossible: for a satellite which should perform its revolution near the surface of Jupiter would employ a little more than 3 hours; which gives a velocity of 1557 miles per minute. But we have already seen that the velocity of the comet would be no more than 700; which therefore is not too great to make a body describe even a circle around Jupiter, very near his surface. If a comet then, in advancing to or returning from the sun, should fall into the system of Jupiter, between him and his first satellite, it might continue to circulate around that planet, in an orbit, if not circular, at least elliptical, and more or less elongated.

For let us suppose AB, pl. 2 fig. 13, to be the orbit of Jupiter; and that this planet is at I, proceeding towards B, and that the comet is in C proceeding towards D, at an angle of about 45 degrees; and that CD denotes the velocity of this comet; which we have found to be greater than that of Jupiter in his orbit. If DE be made equal to the velocity of Jupiter, CE will be the velocity of the comet, and even its route, in regard to Jupiter, supposed to be fixed and without any action on the comet. But on account of this action it would describe an inflected route, such as CF, which would make it fall almost in a perpendicular direction on the orbit of Jupiter, and with a velocity but little greater than that of the first satellite. If at the moment

then when Jupiter was in a point I, so situated as to make IF less than the distance of Jupiter from his first satellite, we do not see what could prevent the comet from assuming around him that circular or elliptical motion suited to its projectile force; and if it should perform the revolution once, it is evident that it ought to continue it.

We however confess, that we have not yet examined this point so far as to be able to assert that it is fully demonstrated. To be assured of it, the following question, which is only a branch of that of the three bodies, but which would require too much intricate analysis for this work, must be answered. Two bodies I and C, pl. 2 fig. 14, which attract each other in the inverse ratio of the squares of the distances, and in the direct ratio of their masses, being projected from the points I and C, according to the directions IB and CG, with given velocities, to find the curves which they would describe. To simplify the problem, we might even suppose one of them, I, to be so large in regard to the second, as to be scarcely turned aside from its course.

PROBLEM XXIV.

How far is there reason to apprehend the shock of a Comet; and what devastation would be thence occasioned on the earth?

What has been said respecting comets in the preceding problem, naturally leads us to examine a question become celebrated by the alarm it occasioned at Paris some years ago. In the year 1774, a Memoir was written by one of the Academicians, of which an incorrect account was propagated, and in which it was said the author announced the speedy approach of a comet to the earth, and that the effect of this approach would be at least, a rising of the waters of the ocean, so as to overwhelm our continent. In consequence of these reports, the people of that capital

were thrown into the utmost consternation and uneasiness. I knew some women who were so terrified, that they did not close their eyes for several nights successively; and I was even obliged, in order to quiet one of them, to assure her that a very great error had been found in the Academician's calculation, and that, on this account, he had fallen into disgrace with the society to which he belonged. The motive, I hope, will plead my excuse with that illustrious astronomer. I am certain that in so good a cause he would have indulged in the same innocent deception; for the object was nothing less than to restore rest and their former lustre to two eyes capable of deranging the observations of the most insensible astronomer. But however, as I have always been devoted, notwithstanding my taste for the abstract sciences, to that charming portion of the human race, I shall endeavour to tranquillize them, and to prove that the danger of being crushed or inundated by a comet, is not so great as to disturb their repose.

Astronomers long ago conjectured that a comet might become fatal to the earth. The celebrated Whiston, whose imagination was rather too powerful for his reasoning faculty, observing a comet, viz, that of 1680, accompanied with an immense tail, began to conjecture that if any of the planets should happen to meet with this tail, it might by its attraction condense its vapours, and be inundated by it. He supposed further, that the deluge had been produced by the same cause; and added, that a comet, such as that above mentioned, if it approached near the sun in returning, might acquire a degree of heat several thousand times greater than that of red hot iron; and consequently might consume our earth. He was of opinion also, that the general conflagration, which is one day to destroy the globe we inhabit, will be occasioned in this manner.

These ideas, in which there is more of singularity than truth, are a sufficient proof of what we have already observed in regard to Whiston's disposition. It is impossible to say what might be the case, if a comet, heated to such a violent degree, should pass very near us. It is probable, considering the rapidity with which it would move, when at its least distance from the earth, that we should not be much incommoded by it. In regard to the danger of being inundated by the vapours of its tail, it is entirely void of foundation; for it may be easily demonstrated, that these vapours, which float in a medium as thin as ether, must themselves be exceedingly rarefied. There is some reason to believe that all this immense tail, reduced to a fluid, such as water, would scarcely furnish enough for an abundant shower. In short, the comet alluded to returns only about every 575 years; consequently it will not appear again till about 448 years have elapsed.

Dr. Halley considered this danger in another manner. This philosopher observed, that if the comet of 1680 had passed through the ecliptic 31 days later, its distance from the earth would not have been greater than the sun's semi-diameter, which is about 441623 miles; and he adds, there can be no doubt that such a proximity between these two bodies would have occasioned a considerable derangement in the motion of the earth; such as a change of its eccentricity and periodical time. May the Author of nature, adds he, preserve us from the shock of these enormous masses, or even from their contact, which is but too possible! He however remarks, that the highly varied position of the orbits of comets, and their inclination to the ecliptic, which in general is very great, seem to be arranged by the Author of nature to secure us from so fatal a catastrophe.

As the astronomy of comets, since the time of Halley, has been enriched with the knowledge of above forty new

ones, it was natural to examine whether there was any of them which, by some change in their position, and the magnitude of their orbits, might become dangerous to our earth. This labour was undertaken by M. Lalande, in consequence of the comet seen in 1770; and he found that there are some of them which, by changing their elements a little, might approach very near to the orbit described by our earth. He showed, at the same time, that there is no great cause for being alarmed at this supposed danger, as several thousands might be betted to one, that if a comet should even pass through the earth's orbit, these two bodies would not fall in with each other.

This danger, as may be seen, was at a sufficient distance to give no great cause of apprehension; but he added, that if we should suppose such a comet to pass at the distance of 45000 miles, it would raise the waters of the ocean, and according to its position occasion a flux capable of covering our whole continent, and of sweeping away all its inhabitants, together with their habitations. This augmented the danger in a considerable degree; for if 10000 could be betted to 1 that the earth and the comet would not be at the same time in the ecliptic, at the distance of a diameter of our globe, no more than 2000 could be betted to 1 that they might not be at the distance of 5 diameters from each other, and consequently that we might not be drowned. But the stake is so great, that even this small chance cannot be considered without some uneasiness; and there are people who would not hold a chance in a lottery where there is only one blank to a hundred thousand prizes.

But fortunately all these calculations are founded on suppositions which, though they may be realized in the course of ages, cannot take place in the present state of the universe: for the orbit of no comet hitherto known falls in with the path described by the earth in the ecliptic. It is indeed true, that, as the orbits of the planets and

comets are subject to insensible variations, it may happen hereafter that the orbit of a comet will intersect that of the earth; but unless it should absolutely coincide with the plane of the ecliptic, that position can be only momentary: and as the revolutions of the comets are exceedingly long, there is a great probability that this position will be changed when the comet passes the ecliptic.

But let us suppose that this position is so constant, that a comet, when it passes the ecliptic, shall be exactly in the same plane, and in the path of the earth; and let us examine, by consulting the laws of probability, what chance there is, that at the moment when the comet is in the ecliptic, the earth will be in a point sufficiently near to come in contact with it. The calculation is as follows:

At the moment when the comet is in the ecliptic, there are so many positions for the earth in the same circle as there might be terrestrial diameters; but only three of these positions are absolutely critical; for there is one which would give a central shock, and the other two, at the distance of a diameter before or behind the place of the comet, would give merely a superficial shock. But it is found, that the circumference of the earth's orbit contains the diameter of the earth 72450 times; and if this number be divided by 3, the quotient will be 24150. Hence if we suppose a comet to be in the path of the earth, 24150 might be betted to 1, that the latter would not be exposed to any shock, even of the most superficial kind. We may add also, that this dangerous position of the comet is, as we may say, the affair of a moment; for in crossing the earth's orbit, it has a velocity of 4000 miles per minute; consequently the danger would not last above 8 minutes. Some danger certainly might be apprehended if the earth, when a comet is in its proximity, should move in so irregular a manner as to fall in with it, and to block up its way.

The danger of our globe being inundated by the rising of the waters of the ocean is still more unfounded, even if the comet should pass at a very moderate distance from it, such as that of 36000 or 40000 miles, which is about a sixth part of the distance of the earth from the moon. It is indeed true, that if we suppose a comet to fall in exactly with the orbit of the earth, it is only 1 to about 7200, that our globe may not be at a greater distance from it than four or five times its diameter; but the rapidity with which the approach would take place, and with which the two globes would afterwards recede, would not allow the waters sufficient time to rise so as to inundate our continent; for a certain period would be required, to communicate to the enormous mass of the waters of the ocean such a movement as that of the flux and reflux. A proof of this is, that the flux, even in the open seas, does not happen till some time after the moon's passage of the meridian; and that the high tides, at the new and full moons, do not occur on those days, but on the following ones. But if a comet should arrive at the earth's orbit, it would traverse our lunar system nearly in the course of an hour; consequently it could produce only a very slight motion in the open seas, such as the Pacific Ocean. Some of the small islands interspersed in it, which are almost on a level with the water, might be overwhelmed; but our continent would absolutely be sheltered from such a misfortune.

The most singular circumstance, in regard to the terror spread throughout Paris, in consequence of an incorrect account being propagated of M. Lalande's Memoir, was, that the greatest danger to which the earth had been exposed in the course of several ages was then past; for of all the comets hitherto known, that of the year 1770 approached nearest to the earth. On the 1st of July it was at the distance of 2250000 miles, which is only about 9 times the moon's distance from the earth.

We shall here observe, that a comet, nearly as large as

the earth, and traversing the heavens with a velocity equal to that above mentioned, would be a grand and magnificent spectacle to astronomers. What a noble phenomenon, a new star of nearly 9 degrees apparent diameter, passing over, by its own motion, about 180 degrees of the heavens in the course of two hours! What astronomer would not wish to behold such an uncommon phenomenon, were it even to occasion some catastrophe to the small uninhabited and already half inundated islands of the vast ocean?

It has however been calculated, that this can never take place, without some great derangement in the motion of our globe. M. Sejour has found, that if a comet, as large as the earth, should pass it, at the distance of about 40000 miles, it would change its periodical revolution; and this revolution, instead of 365 days 6 hours and some minutes, would become 367 days and some hours. But no physical evil would thence result to the universe. Astronomers indeed would have to recalculate their tables, which would be thus rendered useless; chronologists would be under the necessity of altering their method of computing time, and states would be obliged to change their calendars; but this would only furnish matter for new speculations, and afford more occupation to the learned.

THEOREM I.

A pound of cork weighs more than a pound of lead or of gold.—A body weighs more in summer than in winter.

These two propositions, on the first view, may appear to some of our readers a paradox; but when they have read the following reflections, the paradox will vanish.

When bodies are weighed in air, which is commonly the case, they are weighed in a fluid which, according to the laws of hydrostatics, always destroys a portion of their weight equal to that of a similar volume of the fluid: hence

a cubic inch of lead or of gold, for example, when weighed in air, loses of its absolute weight a quantity equal to the weight of a cubic inch of air; and the case is the same with all other bodies. A pound of cork, under the same circumstances, loses a quantity of its weight equal to that of a volume of air of the same size as the cork. But the volume of a pound of cork is much greater than that of a pound of gold or of lead; consequently a pound of cork when weighed in air, has a greater absolute weight than a pound of gold; because, though the weight of the former be diminished by the weight of a greater quantity of air than the latter, they still remain equal.

This reasoning is confirmed by experience; for if a pound of gold or of lead, and a pound of cork, suspended from a good balance, be brought into equilibrium, and if the whole be then covered with the receiver of an air-pump; when the air is exhausted, the cork will be immediately seen to preponderate. In this case, indeed, the weight of the cork is increased by the weight of an equal volume of air; and that of the gold is also increased by the weight of a volume of air equal to itself. But the former is much greater; consequently the equilibrium must be destroyed, and the cork must preponderate. Having thus explained the first paradox, we shall now proceed to the second.

In summer the air is dilated by the heat, and its density being thus lessened, the necessary result is, that the same volume of air is lighter; consequently each of the bodies, brought into equilibrium, loses less of its weight than when the air is denser. But this effect is not produced in the same proportion: the pound of cork, for example, in common air loses 4 grains of its weight, and therefore has an absolute weight of 1 pound 4 grains; while the pound of gold, losing only half a grain, weighs in reality 1 pound and half a grain. In air, dilated so far as to weigh a half

less, a volume of air equal to the volume of cork, will weigh only 2 grains; and the volume of air equal to that of the gold will weigh no more than a quarter of a grain; hence the pound of cork weighed in common air will weigh in this rarefied air 1 pound 2 grains; and the pound of gold 1 pound and a quarter of a grain*; the cork therefore will preponderate.

COROLLARIES.

I. From what has been said, this consequence may be deduced: that two weights in equilibrio at the surface of the earth, will not be so when carried to the summit of a mountain. For, on the summit of a mountain the air is more dilated, and therefore, according to the above reasoning, the equilibrium will be deranged, and the most voluminous body will preponderate.

II. The contrary will be the case if the bodies be in equilibrio at the summit of the mountain, and be then weighed at the bottom of it; or if they be weighed at the surface of the earth, and be then carried to the bottom of a mine. In this case, the most voluminous will become the lightest.

III. It would therefore be attended with advantage, to purchase gold in summer, and sell it in winter; or to purchase it in a cold place, and to sell it in a stove. For gold is generally weighed with copper or brass weights, which in summer lose less of their absolute weight than they do in winter: hence it follows, that in summer they weigh more. By these means therefore, a larger quantity of gold will be obtained in summer than in winter; consequently, by selling it in winter the buyer will get less.

In purchasing diamonds, a contrary method ought to be pursued, because they are weighed with copper weights,

* We must observe that the weights here given by way of example, are French. See the Tables in the second volume.

which are specifically heavier. If a weight of copper then be in equilibrio with a weight of diamonds, in air of a mean temperature; on transporting them into cold air, the copper will preponderate; and the contrary will be the case when they are transported into warmer air. Diamonds therefore ought to be purchased in cold air, or in winter, and to be sold in summer, or in warm air.

The difference in both cases is however so small, that it would be a poor speculation to purchase diamonds in winter, with a view of selling them in summer, or to buy gold in summer in order to dispose of it in winter. But the spirit of the mathematics is capable of showing and appreciating the difference; and though this phenomenon may be of little use in traffic, it is nevertheless a physical and a mathematical truth.

THEOREM II.

Two homogeneous weights which are in equilibrium at the surface of the earth, when suspended from a balance with unequal arms, will not be so when carried to the summit of a mountain, or to the bottom of a mine.

Let us suppose a balance, pl. 3 fig. 15, with unequal arms, AB and BD, to be loaded with the two weights P and Q, which are in equilibrio, and therefore unequal: if the balance be in a horizontal situation, these weights, as they tend to the centre of the earth, which we suppose to be C, will form with the balance the unequal angles CAB and CDB: consequently the angle A, at the larger arm, will be the least. From the point B, let fall on the lines of direction AC and DC, the perpendiculars BE and BF: by the laws of mechanics these perpendiculars will be in the reciprocal ratio of the weights, so that BE will be to BF, in the same ratio as the weight P to the weight Q: that is to say, the product of P by BF will be equal to that of Q by BE.

Now let the balance be removed nearer to the centre of direction, or, what amounts to the same thing, let the centre be brought nearer, as to *c* for example, by which means the new directions will be A*c* and D*c*; and let B*e* and B*f* be the new perpendiculars to these lines of direction: if the ratio of B*f* to B*e* be the same as that of BF to BE, or of Q to P, there will still be an equilibrium; but it may be easily demonstrated, that this ratio is no longer the same: consequently the product of Q by B*e*, will not be equal to that of P by B*f*; and therefore there will no longer be an equilibrium. It can even be shown that, when the centre is brought nearer, the ratio of B*e* to BE, will be less than that of B*f* to BF; hence it follows that B*e* will be less than is required to make these ratios equal; and in this case the weight, nearest the point of suspension, will preponderate.

For the same reason, the contrary effect will be produced, if the balance be removed farther from the centre, by transporting it, for example, to the summit of a mountain.

It may here be asked, why does the equilibrium subsist, notwithstanding this demonstration? the reason is plain: the centre of the earth is always at so great a distance, compared with the length of such a balance, that the lines of direction are sensibly parallel, at whatever height or depth above or below the surface of the earth they may be placed. The difference therefore, from an exact equilibrium, is so small, that it cannot be observed with the most perfect balances constructed by the art of man.

PROBLEM XXV.

Of the Central Fire.

Those acquainted with the phenomena observed by different philosophers, in the interior parts of the earth, cannot help acknowledging that the surface, even in our cli-

mates, is subject to vicissitudes of heat and cold which we experience. At a certain depth, not very great, for it is sufficient to descend only about a hundred feet, the heat is constantly the same, that is to say, about 10 degrees of Reaumur's thermometer, or 54½ of Fahrenheit. This is observed the same in all climates, and in all countries.

It is evident therefore, that the earth, independently of the variable heat of the sun, has a source of heat peculiar to itself, from whatever cause it may arise.

Nay, we shall here show that the degree of heat which the presence of the sun, during several months of the year, adds to the internal heat of the earth, or that which it loses by his absence, is only a small part of the internal heat.

To suppose indeed that the degree of cold which freezes water, is the zero, or the 0 degree of heat, would, as before observed, be erroneous; for heat and cold are merely relative terms. If the common liquors of our earth were of the nature of spirit of wine, as the fluids of our bodies would then be proof against congelation, unless they were exposed to a diminution of heat beyond that at which spirit of wine freezes, it is more than probable that we should experience no disagreeable sensation by living in a temperature similar to that which congeals water; on the other hand, if our liquors were of such a nature as to freeze at the degree at which wax begins to become fixed, we should probably experience at this temperature the same sensation as we experience at that which congeals water. Every degree above that term would be heat, and every degree below it would be cold.

Besides, there is no doubt that an absolute degree of cold would congeal all liquors. But spirit of wine congeals only at 29 degrees below zero of Reaumur's thermometer: there is still heat therefore at 28 degrees, though, on account of the disagreeable sensation which we experience, we call it severe cold. We cannot however sup-

pose that this is the ultimate degree of cold. Several reasons, which it would be too tedious to explain here, give reason to think that this absolute degree of cold is a thousand degrees, at least, below the zero of Reaumur's thermometer.

But let us confine ourselves to the 240th degree, which we shall assume as that of the absolute privation of heat, and let us suppose a thermometer the zero of which is placed at that term ; or, let us substitute, in one of our common thermometers, the degree 240 for that usually marked zero, which is only the degree of the congelation of water : in this case we shall have 250 degrees for the term which we call temperate. But taking the mean degree of heat during summer in our hemisphere, it will be found, that it does not exceed 26 degrees above that of the congelation of water, and consequently 16 above temperate: hence we have for this degree of heat the absolute degree of 266. The thermometer therefore will vary from temperate to the greatest heat, 16 degrees in 250, which is somewhat less than the 15th part.

It will be found, in like manner, that the mean degree of the cold of winter, in our northern hemisphere, is 6 degrees below congelation, according to the rate of Reaumur's thermometer ; that is to say, 16 degrees below temperate : hence the mean diminution of heat below temperate, occasioned by the absence of the sun, is about a 15th part of the heat marked by the degree 10. Hence it follows, that from winter to summer, the variation of the heat is at most only $\frac{1}{8}$, or as 7 to 8. But it is highly probable, as M. Mairan has shown, in the Memoirs of the Academy, for 1765, and Buffon in the supplement to his Natural History, that the ratio of this variation is much less.

The former fixes it at $\frac{1}{31}$, or as 31 to 32 ; and the latter at $\frac{1}{50}$, or as 50 to 51. But let us confine ourselves to the ratio we have formed, in order that we may set out from a principle fully proved.

The conclusion we thence form, and it is a consequence which cannot be denied, is as follows: In the globe of the earth there is a degree of constant heat, which is at least 7 or 8 times as great as that produced by the presence of the sun while he illuminates it in the most advantageous manner for heating it. Here then we have a fire, or source of heat, which may be called central. It now remains that we should examine the cause of it.

According to some philosophers, this fire is merely the effect of the continual effervescence occasioned by the mineral matters inclosed in the bowels of the earth, when they meet and become mixed with each other. Iron, which appears to be universally diffused throughout nature, and which communicates its colour to argillaceous earths, produces, as is well known, a violent effervescence with the vitriolic acid, which is also very abundant. Hence, say they, is the cause which excites and maintains in the bowels of the earth that continual fire by which it is heated, and which often manifests itself by the eruptions of volcanoes, dispersed in considerable numbers over its surface: volcanoes, according to these philosophers, are the chimneys or spiracles of this central fire.

It would be difficult to show the absolute falsity of this opinion: but it does not appear that a fire of this nature can be general throughout the bowels of the earth. The number of the volcanoes, which exist at its surface, is too small to have a cause so general: there are even very few of them that burn without interruption. The central fire, however, if it be real, must be constant and perpetual; and therefore it is necessary that we should recur to some other cause.

Another, which has long appeared to possess a great degree of probability, is as follows. The central heat, say some philosophers, is nothing else than the heat which the body of the earth, continually warmed by the sun, has acquired in consequence of the presence of that luminary.

But let us render this idea more familiar by an experiment.

If a globe of iron, which revolves round its axis in a determinate time, and which has been cooled to the degree of ice, as well as the surrounding air, be exposed before a fire, the impression of the fire will first heat the surface, and the heat will gradually penetrate to its interior parts; so that after a great number of revolutions the globe will acquire such a degree of internal heat, that it will be incapable of receiving more; and the presence of the fire will only serve to make it retain that which has already been communicated to it.

It may be readily conceived also, that the nature of the globe, or its distance from the fire, may be such, that this constant degree of heat shall not be very remote from that of the congelation of water.

In this case, what will be the result? as it is the surface of bodies that always begins to lose the heat they have acquired, because it loses more by its contact with the air than is furnished to it by the interior parts, it will necessarily happen, if the surrounding air be nearly at the degree of congelation, that the part of the surface which is illuminated obliquely, or that which by a slower revolution is opposite to the side next to the fire, will lose a little of its heat; and as we suppose the mean heat, which the globe has acquired, to be not far distant from the degree of congelation, like the temperature of the earth, the surface, in those parts less favourably exposed to the action of the heat, may assume a degree of cold equal to that of ice. Consequently, if there were on the surface of this globe some matter, such as wax or water, susceptible of melting and congealing alternately, it would certainly experience these alternations: it might even happen that it would remain constantly frozen in the neighbourhood of the poles; thus it would alternately melt and be con-

gealed, in the mean parts between the poles and the equator, and it would always remain fluid in the environs of the equator.

But this is exactly what takes place at the surface of the earth: exposed for a great number of ages to the benign influence of the sun, the heat has been communicated to its most interior parts, and this internal heat is what is called the *central fire:* it is continually receiving an additional quantity, and this makes up for the loss of that dissipated at its surface, by the contact of the air which is less heated. In a word, as the iron globe above mentioned, would possess, to the depth of several lines below its surface, a heat nearly constant, the degree of heat which prevails to some depth below the surface of the earth is, in like manner, almost invariable *.

But it is difficult to believe that the mass of the earth, if deprived of all heat, and exposed to the sun, could ever acquire that heat which it seems to possess. How many ages, or millions of ages, would be necessary, before a heat, so feeble as that of the sun, could melt an ocean entirely congealed, and insinuate itself into its bowels! In our opinion, the ice melted at the line by the presence of the sun would have been again congealed during the twelve hours of his absence; so that the globe exposed in this state to the sun, would have remained in it to eternity, had not some other powerful cause suddenly communicated to it that fund of heat, which by vivifying nature renders the earth habitable, and susceptible of vegetation.

A third cause of the central heat remains to be examined: it is that of Buffon.

According to this celebrated philosopher, the earth and other circum-solar planets were formerly a part of the sun,

* We say *almost* invariable, because we are acquainted with few observations of the thermometer in subterranean places, besides those made in the caverns below the observatory at Paris.

and were detached from its surface by a comet, which entering it to some depth, projected the fragments to different distances. While they were in a state of fusion, each of them, in consequence of the laws of universal gravitation, must necessarily have assumed a globular form. The more considerable masses, such as Venus, the Earth, Mars, Jupiter, and Saturn, being projected in this manner, flew off in a tangent, which, together with the attractive force of the sun, made them describe, around that luminary, orbits more or less elongated. Such of these new planets as had smaller fragments accidentally in their neighbourhood, overcame them in some measure; and these fragments, turning around the larger ones, in consequence of the same laws, became their satellites. In this manner, the earth, Saturn, and Jupiter acquired those moons by which they are accompanied.

If this generation of the earth and circum-solar planets be admitted, it is evident that these globes were at first fluid; and this may serve to explain their formation into oblate spheroids; for the earth and other planets must have necessarily been, during the course of some time, either in a state of fusion or of semi-fluid paste; otherwise their diurnal motion could not have given them that form which they possess. But let us set out from their supposed state of fusion. Masses of so considerable a size as Venus, the earth, &c, could not certainly cool in a day or a year, nor even in twenty centuries. They first passed from a state of fusion to that of solidity; they remained long impregnated with a quantity of fire, which rendered them uninhabitable. At length, their surface has gradually cooled, till they retained only that degree of heat necessary for animal life, and to render them susceptible of vegetation. The interior parts of the earth still possess a more considerable degree of heat than the surface, and this

heat must go on increasing towards the centre. Such is the central fire.

But by a necessary consequence of the cause of this fire, it must always decrease, so that a small portion of it is every day lost. It appears indeed, that the fertility of the earth daily decreases, and that mankind degenerate, both in size and in strength. This diminution however cannot be proved: we have not been long enough possessed of an instrument proper for measuring heat; it is not much above half a century since comparative thermometers were invented. But if it be found, 500 years hence, for example, that the constant heat in the caverns below the observatory of Paris, is not more than 7 or 8 degrees, instead of 9¾, which it is at present, the progressive cooling of the mass of the earth will be a fact, which can no longer be doubted, whatever may be the cause of that heat, and of its decrease.

We must however observe, notwithstanding our respect for the illustrious philosopher who is the author of this idea, that there are many difficulties in regard to this formation of the earth and planets, which it is not easy to resolve.

1st. If the planets were formed in this manner, it is difficult to conceive how the comets could have a different origin; and if the latter were planets circulating around the sun, the Sovereign Cause, who arranged the universe, could, with equal ease, have formed the planets in the same manner.

2d. It seems difficult to reconcile with the laws of motion and universal gravitation, the position and dimension of the orbits of these new planets; for according to what has been demonstrated by Newton and others, since they proceeded from the sun, in a line nearly a tangent to his surface, and from a point of his surface, they ought at each

revolution to pass through the same point: this however is not the case; on the contrary, the orbits of the planets are nearly circular.

It appears also, that in this projection the largest masses could not go to the greatest distances, and describe the largest circles; it would seem that the smallest planets ought to be the most distant from the sun; for if several bodies are thrown promiscuously by any force whatever, the smallest will be projected with the greatest velocity.

In short, the effect of such a projection is beyond calculation; and it may be said also that the comet in question, while it ploughed the surface of the sun, communicated to it an impulse which made it change its place. This comet indeed, which could carry with it at once such masses as the planets, must have been of an enormous size, and impinging against the sun with immense velocity, could not fail to cause a small displacement of that luminary, which is in the centre of our system, in a kind of inert state.

Remark.—Whatever may be the fate of these ideas, the following are some of the consequences which Buffon deduces from his system on the formation of the earth, and which are too curious to be omitted in a work of this kind.

Setting out from his principles on the formation of the earth and the planets, Buffon made a series of very curious experiments, to determine in what ratio the refrigeration of different masses of matter takes place, according to their nature and size; and from these experiments he concludes:

That a globe, such as Mercury, must have required 2127 years, to be consolidated to the centre; 24813 to become so cold that it could be touched; 54192 to be reduced to its present temperature; and in the last place, that it would require 187775 to become so cold as to have only the 25th part of its present temperature; for the

sake of brevity we shall call these the 1st, 2d, 3d, and 4th epochs.

That Venus must have employed 3596 years in the first epoch; 41900 in the second; 91600 in the third, and that 228540 would be required for the fourth.

That the earth employed in the first epoch 2936 years; in the second 34270; in the third 74800; and that 168125 will be necessary before its temperature is reduced to a 25th part of what it is at present.

The earth therefore has existed 112 thousand years; and hence it follows, that Mercury passed the degree of the present temperature of the earth 30000 years ago; and that it has even lost already six of the 25 degrees which remained to it.

That the moon employed only 644 years in the first epoch; 7515 in the second; 16409 in the third, and 72514 in the fourth.

Hence, the moon, 15000 years ago, was reduced to such a degree of coolness, as to have only a 25th part of the heat of our earth. It needs therefore excite no astonishment, that she should appear to us as an accumulation of ice, and that she exhibits no signs of living nature. If she had inhabitants, they must long ago have been congealed.

Mars employed 1130 years in becoming solid to the centre: 13000 in the second epoch; 28538 in the third; and 60,300 in the fourth: consequently this planet has been useless for 9 or 10 thousand years.

In regard to Jupiter, the case is different: he must have employed 9400 years in the first epoch, and will require 110,000 for the second. But it is only 112000 years since the earth and Jupiter were formed; consequently 7 or 8 thousand years will be necessary, before Jupiter can be cooled to such a degree, as to admit placing the foot upon it, without being burnt. When it attains to this epoch,

it will require 240400 years before it be reduced to our present temperature; and then 483000 to lose nearly the whole of its heat. This globe then will begin to be habitable, when we are rendered absolutely torpid with cold.

In the last place, Saturn employed 5140 years in becoming fixed to the centre; and required 59900 before he was fit to be touched: the duration of his third epoch will be 130800 years; and of this epoch, above 47000 years have already elapsed; so that it will be above 84000 years before his temperature is reduced to that of the earth.

In regard to the satellites, we shall only observe that the greater part of them are in a habitable state, and fit for vegetation, the fourth of Jupiter excepted, which is already advanced in its fourth epoch: the third of Saturn is nearly at the same degree of temperature as the earth, but rather somewhat warmer; the fourth is considerably advanced in its fourth epoch; and the fifth must have been a mass of ice for nearly 50000 years.

PROBLEM XXVI.

Construction of the Barometer.—To measure the Variations of the Gravity of the Air.

The barometer is one of those instruments, for the discovery of which we are indebted to the 17th century, a period that gave birth to a great many happy ideas. This instrument, which serves to determine the variations that take place in the gravity of the air, derives its name from two Greek words, *βαρος* and *μετρειν*, the former of which signifies *weight*, and the latter *to measure*. It was the invention of Torricelli, a disciple of the celebrated Galileo, who employed it chiefly to prove the gravity of the air in which we live and breathe. But it was Pascal who first discovered its variations, by means of the famous experi-

ment which he caused his brother-in-law to make on the Puy-de-Dome, a mountain in the neighbourhood of Clermont. It enabled him to demonstrate, in the most evident manner, the gravity of the air, which some still persisted to deny, notwithstanding the experiment of Torricelli.

A barometer may be easily constructed without much expence. Provide a vessel, some inches in depth, filled with mercury, and a glass tube 30 or 35 inches in length, hermetically sealed at one end. Invert the tube, that is to say turn the sealed end downwards, and fill it with mercury; apply your finger to the top so as to keep it shut, and having turned the sealed end uppermost, immerse the open end into the mercury in the vessel, and remove your finger, so as to allow the mercury in the tube to have a communication with that in the vessel: the column of mercury contained in the tube will then fall, but in such a manner that its upper extremity will remain about 28 inches, more or less, above the level of the mercury in the vessel, if the experiment be performed at a small height only above the level of the sea. In this manner you will have a barometer constructed; and if by any contrivance you can fix the tube, thus immersed in the mercury, the end of the column of mercury will be seen to fluctuate between the height of 27 and 28 inches, or 29 and 30 inches English, according to the different constitutions of the atmosphere.

This is a barometer of the simplest kind, and such as it was when it came from the hands of Torricelli. At present, a glass tube, from 33 to 36 inches in length, is employed: it is hermetically sealed at the one end, and bent at the other, after having been dilated at an enameller's lamp, so as to resemble a phial, as seen in the figure, pl. 3, fig. 16. This tube is filled by inclining it, and pouring in the mercury at different times, in such a manner, that when placed upright the mercury in the phial rises only to about half

its height, as AB. The difference between the line CAB and the line DE, at which the mercury maintains itself, is the height of the column which counterbalances the pressure of the atmosphere, as may be easily conceived. This glass tube, when filled with mercury, is affixed to a piece of board, more or less ornamented; the interval between the 28th and 31st inch above CB, is divided into tenths, and the words *settled weather, fair, changeable, rain, stormy*, are inscribed at equal distances, beginning at the line of 28 inches. Such is the construction of the barometers commonly sold in the shops; but to render them good, some precautions are necessary.

1st. The diameter of the phial, or lower receptacle of the mercury, must be considerably larger than that of the tube, otherwise the line AB, as may be easily perceived, will sensibly vary as the mercury rises or falls.

2d. The mercury must be purified from air as much as possible, or at least to a certain degree; and the tube ought to be heated and rubbed in the inside, to remove the moisture and dust which generally adheres to it; otherwise there will be a disengagement from it of air, which occupying the upper part of the tube, will, by its elasticity, form a counterpoise to the gravity of the atmosphere, and cause the column to remain lower than it ought to do. This air also, being dilated by heat, will produce on the column of mercury a much greater effect, so that its motions will depend both on the heat and gravity of the air, while it ought to depend on the latter cause alone.

PROBLEM XXVII.

Does the suspension of the mercury in the barometer depend on the gravity or the elasticity of the air?

We introduce this question, merely because it has been discussed in some books of natural philosophy, the authors

of which have determined that this phenomenon ought to be ascribed to the elasticity, and not to the gravity of the air. The following analysis will show how ill founded is the reasoning of those who entertain this opinion.

In this question there are two cases. In one of them the barometer is supposed to be placed in the open air; and this properly is the one which we here propose to examine. In the other, it is supposed to be shut up in a room so close, that no air can penetrate to it; or under the receiver of an air-pump, from which the air is excluded.

It is evident, in the second case, that the cause of the suspension of the mercury is the elasticity of the air alone; but to extend this to the case where the barometer is exposed to the open air, is reasoning, we will venture to say, in a manner unworthy of a philosopher.

To ascertain to which of the two causes the suspension of the mercury in the barometer, exposed to the open air, ought to be ascribed, let us suppose the air to be deprived of its weight or elasticity; and let us examine what would be the consequence.

If the air were deprived of its elasticity, it is evident that it would fall back upon itself, and form around the earth a kind of ocean of a peculiar fluid, the height of which would be much less than that of our atmosphere; but it would still have the same weight, for a ball of air which has lost its elasticity, and is reduced to a less volume, weighs as much as it did, when in consequence of its elasticity it occupied a much larger space. The mercury in the barometer, if immersed to the bottom of this fluid, would sustain neither more nor less pressure, and consequently would maintain itself at the same height.

Let us now suppose, on the other hand, that the air, preserving its elasticity, has lost its gravity. In this case, as the parts of the air would experience no impediment to

recede from each other, that is to say, as their elasticity would not be compressed by the weight, resulting from the force exercised by the superior on the inferior parts, the air would be dissipated, without exercising any action on the column of mercury; unless we suppose, at the top of the atmosphere, a transparent arch to confine the elasticity of the air; for it is necessary that a spring, to exercise an action with one of its extremities, ought to rest against some fixed point with the other. But as such a supposition is ridiculous, it is evident that what confines the spring or elasticity of the air is its weight.

Since the air then, if deprived of its weight, and endowed with all the elasticity possible, would have no action on the mercury in the barometer; and, on the other hand, as it would still maintain the mercury at the same height, though deprived of its elasticity, provided it retained its weight, it may be asked to what cause this suspension ought to be ascribed? The answer is so easy that it is needless to mention it.

PROBLEM XXVIII.

Use of the barometer to foretel the approach of fine or of bad weather. Precautions to be observed in this respect, in order to avoid error.

One of the principal uses of the barometer, is to foretel the approach of fine or of bad weather. Experience has indeed shown that the rise of the barometer, above its mean height, is generally followed by fine weather; and, on the other hand, that when it falls below that height, it indicates the continuation or approach of rain. These rules however are not absolutely general, and infallible. Wind also has a great influence on the rise or fall of the mercury in the barometer; and therefore we think it necessary to give a few rules, founded on observation, which

may enable those who have barometers to form a more certain opinion respecting their indications.

1st. The rising of the mercury announces, in general, fine weather; and its fall is a sign of bad weather, as rain, snow, hail, or storms.

2d. During very hot weather, a sudden fall of the mercury indicates a storm of thunder.

3d. In winter, the rising of the mercury presages frost; and in the time of frost, if the mercury falls three or four lines, it announces a thaw; but if it rises during a continued thaw, snow will certainly follow.

4th. When bad weather takes place immediately after a fall of the mercury, it will not be of long duration; and the case will be the same in regard to fine weather, if it speedily follows a rise of the mercury.

5th. But during bad weather, if the mercury rises a great deal, and continues to do so for two or three days, before the bad weather is past, a change may be expected to fine weather, which will be of some duration.

6th. In fine weather, if the mercury falls very low, and continues so for two or three days before rain takes place, there is reason to conclude that the rain will be violent, of long duration, and accompanied with a strong wind.

7th. Irregularity in the motion of the mercury, announces uncertain and variable weather.

Such are the rules given by Desaguliers, according to a series of observations made by Mr. Patrick, a celebrated constructor of barometers, at London.

But there can be no doubt that they are liable to exceptions and variations.

It is known, for example, that in the countries situated between the tropics, the barometer scarcely varies; on the borders of the sea it always maintains itself within a

few lines more or less of 28 inches*. This is a phenomenon difficult to be explained; and no reason ever yet assigned for it, appears satisfactory. Those therefore would be deceived who should apply the above rules to a barometer, transported to these countries.

It frequently happens also, that the falling of the mercury takes place without any rain; but in that case a considerable degree of wind prevails, if not in the lower, at least in the upper part of the atmosphere; for Mr. Hauksbee contrived an experiment, by which he produced that effect on the barometer artificially.

PROBLEM XXIX.

How comes it that the greatest height of the barometer announces fine weather, and the least the approach of rain or of bad weather?

Those not acquainted with the progress of the barometer, and who are ignorant that the mercury generally rises when the sky is serene and the air very pure, and that its fall, on the other hand, generally takes place before rain, would no doubt judge differently, and suppose that the mercury ought to fall when the air is serene and pure, and to rise when the air is charged and impregnated with vapours; for it is natural to believe, that pure and serene air is lighter than that which holds in solution a great deal of vapours. The progress of the mercury in the barometer is however quite the reverse; it is therefore a phenomenon which has been the subject of much discussion among philosophers, but without success; for all their explanations overturn themselves, and not one of them will bear examination.

* The natural mean height of the barometer is 30 English inches. On this subject, see the remark added to the table of the heights of mountains, *Prob.* 44.

Some philosophers have said: the air is never more serene and more transparent than when well charged with vapours, or at least when they are perfectly dissolved and combined with it; for it is the property of perfect solutions to be transparent: it is not therefore astonishing that the mercury, being pressed down by a greater weight, should in this case rise. But when the aqueous vapours are separated from the air by any cause, they disturb its transparency, and begin to be precipitated: they no longer contribute to its weight, since they are not suspended in it; and as a proof of this, they quote the celebrated experiment of Rammazini, which is as follows.

Take a narrow vessel, several feet in height, and having filled it with water, place upon it a bit of cork, with a leaden weight suspended from it by a thread, so that the whole shall float. When the vessel has been thus prepared, put it into the scale of a balance, and load the other scale until an equilibrium is produced. If the thread by which the lead is attached to the cork be then cut, it is observed that, while the lead is falling, this side of the balance is lightened, and the other preponderates. Hence it is evident, say the above philosophers, that while a weight is falling in a fluid, it exercises no pressure on the base; consequently, while the vapours, collected in the air, are precipitating themselves, or after they begin to be precipitated, the air is lighter, and the mercury becomes charged with a less weight.

This reasoning, which is that of Leibnitz, is exceedingly ingenious. Unfortunately however the experiment of Rammazini proves only, that the scale of the balance is unloaded during the fall of the weight; but it does not prove that the bottom of the vessel is eased by the quantity of the weight which is falling; for these are two things very different. Recourse must therefore be had to another explanation.

For our part, we agree with M. de Luc*, that the only cause of the falling of the mercury in the barometer, on the approach of rain, is the diminution of the gravity of the air, when saturated with aqueous vapours. In our opinion therefore, the air is never heavier than when it is exceedingly pure; and we are inclined to think so for various reasons.

The vapours seen floating in the atmosphere, under the form of clouds, are nothing but a solution of water in air: while this combination is imperfect, it is only semi-transparent, as is the case in regard to all solutions. The vapours, when in that state, are observed to rise in the atmosphere, and hence there is reason to conclude that they are lighter than air. The state of the air, in regard to gravity, when thus charged with vapours, may be deduced from the gravity of the vapours themselves; and since they are lighter than the air in which they ascend, we must infer that the air in which they are dissolved is lighter than pure air.

But it may be said, how can we conceive that air combined with a fluid heavier than itself should become lighter? It may be replied, that if the combination here meant were only the interposition of watery particles between those of the air, as might have been believed, before the improved state of chemistry had thrown light on a number of questions relating to the most common phenomena, this would be impossible. But this is not the mechanism of solutions, or of the combination of bodies with each other; each particle of the solvent combines with each particle of the dissolved body, and it is not improbable that this takes place here by the medium of fire, which is far lighter than either air or water. We can therefore form no conclusion respecting the weight of compound particles from that of

* *Traite des Barometres, Thermometres*, &c. Geneve, 1770, 2 vols. 4to.

the separated particles. Besides, in this state of combination, they may be endowed with a greater repulsive force; and this even seems to be very probable, since the expansibility of water, when reduced into vapour, is immense. There can be no absurdity then in asserting, that air charged with vapours is lighter than pure air. This will perhaps be demonstrated some day *à priori*, by chemical processes; and should this be the case, philosophers will be much surprised at the difficulty which has hitherto occurred in attempting to explain the falling of the mercury in the barometer, on the approach of rain.

PROBLEM XXX.

Of the Compound Barometer.

It has already been seen that a column of Mercury of about 30 inches in height is necessary to counterbalance the weight of the atmosphere; and hence it follows, that a simple barometer can never be at a less height, unless some fluid heavier than mercury be employed. As this length has been found inconvenient, attempts have been made to shorten it; with a view, as would seem, of confining it within the same extent as the thermometer, which may be reduced to a much less size. The method in which this has been accomplished, is as follows:

The principle of the construction of these barometers, consists in opposing several columns of mercury to one of air; so that these columns taken together shall have the same length, viz, 30 inches, which one ought to have in order to be in equilibrium with the weight of the atmosphere. Consequently, 30 inches, or the common height of the mercury, must be divided by the length intended to be given to the barometer: the quotient will give the number of columns of mercury which must be opposed to the weight of the air.

Thus, if a barometer only 15 or 16 inches in length be

required, it must be formed of three glass tubes, joined together by four cylindric parts of a larger size, as appears pl. 3 fig. 17. Two of these tubes must be filled with mercury, and have a communication with each other, by means of the third, which ought to be filled with a lighter fluid. Thus the first branch, from D to E, is filled with mercury: the second, from E to F, is half filled with coloured oil of tartar, and half with carob-bean oil; and the third, from F to G, is filled with mercury. This arrangement therefore is the same thing, as if these two columns of mercury were placed one above the other; for it may be easily perceived that the column of mercury FG, presses on the first by means of the intermediate column FE, exactly in the same manner as if it were above it. In this kind of barometer, it is the separation of the two liquors, contained in the branch EF, that serves to indicate the variations of the weight of the atmosphere; and for this reason these two liquors must be of different colours, and of different specific gravities, to prevent them from mixing.

To fill this barometer, stop the aperture A, and pour mercury into the two lateral branches through the aperture B; then pour the two liquors into the middle branch, through the same aperture; after which it must be hermetically sealed.

If a barometer only 9 or 10 inches in height were required, 30 must be divided by 9 or 10, which will give 3; consequently, three branches containing 9 or 10 inches of mercury, and two communicating branches filled with oil of tartar and carob oil, will be necessary. This barometer, consisting of five branches, is represented pl. 3 fig. 18. It may be proper to observe, that the height of each branch ought to be estimated by the difference of the level of the liquor in the upper reservoir, and that of the liquor in the lower.

This construction, invented by M. Amontons, has the

advantage of lessening the height of the barometer, which is sometimes inconvenient; and of rendering it fitter for being employed under certain circumstances as an ornament. But it is to be observed, that this advantage is gained at the expence of exactness. M. de Luc, who has made barometers his particular study, and who has treated the subject better than any other person, says, that he never was able to obtain a tolerable instrument of this kind. The intermediate column acts as a thermometer; and those who have attempted to prove that this does not injure the accuracy of the instrument, did not reflect, that their reasoning is true only when the line of the separation of the two colours is in the middle of the height of the tube.

PROBLEM XXXI.

What space would be occupied by a cubic inch of air, if carried to the height of the earth's semi-diameter?

We have already mentioned that air, in consequence of its elasticity, when charged with a double weight, is reduced to one half of its volume, and so on in proportion; at least as far as has hitherto been found by the experiments made on that subject. For the same reason, when freed from the half of the weight which it supports, it occupies a double space; and a quadruple space, when it has only a fourth part of the weight to support. Thus, for example, on ascending a mountain, when it is found that the mercury has fallen half the height at which it stood at the bottom of the mountain, it is concluded that, being freed from half the weight which it supported when in the plain, it has been dilated to double the volume, or that the stratum of the surrounding air has only half the density of that at the bottom of the mountain; for the density is in the inverse ratio of the space occupied by the same quantity of matter.

This law of the dilatation of the air, in the inverse ratio of the weight with which it is loaded, has enabled geometricians to demonstrate, that as one rises in the atmosphere, the density decreases, or rarefaction increases in a geometrical progression, while the heights to which one rises increase in arithmetical progression. Hence, if it be known to what height we must rise to have the air rarefied one fourth, for example, or reduced to three fourths of the density which it has on the borders of the sea, we can tell that at a double height, its density will be the square of $\frac{3}{4}$, or $\frac{9}{16}$; at a triple height it will be the cube of $\frac{3}{4}$, or $\frac{27}{64}$; in short, at a hundred times the height, it will be the 100th power of $\frac{3}{4}$, &c. Or, if the ratio of the density of the air, at the height of 1760 yards, or 1 mile, to the density of the air on the borders of the sea, has been determined, and if we call this ratio D, we shall have D^2 for the expression of that ratio at the height of 2 miles; at 3 miles it will be D^3, &c; and at n miles, it will be D^n.

But, it is known by experiment that at the perpendicular height of a mile, above the level of the sea, the mercury, which on the borders of the sea was at the height of 28 inches, or 336 lines, falls to 22 inches 4 lines, or 268 lines, or the height of the mercury at that elevation is expressed by the fraction $\frac{268}{336}$, unity being the whole height. Hence it follows, that the ratio of the density of the air at that height, to the density of the air on the borders of the sea, is expressed by that fraction; consequently to find what this ratio would be at the height of the earth's semi-diameter, we must first know how many miles are contained in that semi-diameter. Let us suppose that there are 3000. We must therefore raise the above fraction $\frac{268}{336}$, or $\frac{67}{84}$, to the 3000th power, which may be easily done by means of logarithms; for taking the logarithm of $\frac{67}{84}$, which is $-0{\cdot}0982045$, and multiplying it by 3000, we shall have for the logarithm of the required number

— 294·6135000; which indicates that this number is composed at least of 295 figures. We may therefore say, that the density of the air which we breathe at the surface of the earth, is to that which we should find at the height of the earth's semi-diameter, as a number consisting of 295 figures, is to unity. It is needless to make a calculation to prove, that the sphere even of Saturn does not contain as many cubic inches, as are expressed by that number; and consequently that a cubic inch of air, carried to the height of the earth's semi-diameter above its surface, would be extended in such a manner, as to occupy a space greater than the sphere of Saturn.

We shall here just observe, that this rarity would be still greater, for the following reason. We have supposed the gravity uniform, which is not the case; for as gravity decreases in the inverse ratio of the distance from the centre of the earth, it thence follows, that in proportion as one rises above the surface, this gravity is diminished; so that at the distance of a semi-diameter from the earth, it is only a fourth part of what it was at the surface: every stratum of air then will be less loaded by the superior strata, since they will weigh less at the same height, than on the preceding supposition; consequently, the air will be more dilated. Newton has shown the method of making the calculation; but for the sake of brevity we shall omit it.

Remark.—The extreme rarity of the air, at a distance so moderate, may serve as a proof of the great tenuity of the matter with which the celestial space is filled. For if its density were every where the same as it is at the distance of the earth's semi-diameter, it may be easily perceived how little the planetary bodies can lose of their motion by traversing it. The moon, during the many thousand years she has been revolving round the earth, cannot yet have displaced a quantity equal to a cubic foot of our air.

PROBLEM XXXII.

If a pit were dug to the centre of the earth, what would be the density of the air at the different depths, and at the bottom of it?

We shall begin our answer to this question by observing, that one could not proceed to a very great depth, without coming to air so highly condensed, that a person would float on it, in the same manner as cork does on mercury.

This is evident, if we suppose the gravity at the different depths of the pit to be uniform; for at the distance of a semi-diameter below the surface, the density must be to that of the air at the surface in the inverse ratio of the density of the latter, to that of the air at the distance of a semi-diameter above it. But we have seen by what a number the rarity of the latter is expressed; and the same number will express the condensation at the centre.

Quicksilver is not quite 14000 times as heavy as the air which we breathe; and therefore the air at the centre would be thousands of millions of millions &c, of times denser than mercury. But, for the sake of amusement, since we are on the subject of philosophical recreations, let us examine the most probable hypothesis of the gravity which prevails in the case stated in this problem. The gravity would not be uniform; it would decrease on approaching the centre, being exactly as the distance from the centre. But Newton has shown that as the squares of the distances, from the centre, in this case decrease arithmetically, the densities would increase geometrically.

We must then first find what would be the density of the air at a determinate depth, such as 1000 toises, for example. But this is easy, on account of the proximity of that depth to the surface; for if the density at the surface be expressed by unity, that at the depth of 1000 toises or a mile below it, will be the inverse of 1000 toises above

it. But the latter was expressed by $\frac{67}{84}$, consequently the expression for the former will be $\frac{84}{67}$, or $1 + \frac{17}{67}$; hence the density being 1, at the distance of 3000 miles from the centre, the density at the distance of 2999, will be $\frac{84}{67}$. Let us then square 3000, which gives 9000000, and also 2999, which gives 8994001; the difference between these squares is 5999, by which if 9000000 be divided, we shall have the quotient 1500, for the number of squares decreasing arithmetically at the same rate, that are contained in that square. If the logarithm of $\frac{84}{67}$, which is 0·0982045, be multiplied by 1500, the product will be 147·3067500, or the logarithm of the density at the centre, that at the surface being 1. But the number corresponding to this logarithm would contain 148 figures at least; whence it follows, that the density of the air, at the centre of the earth, would be to that at the surface, as a number consisting of 148 figures, or at least unity followed by 147 ciphers, to unity.

Were it required to determine at what depth the air would have the same density as water, it will be seen by a calculation founded on the same principles, that it would be at the distance of 30 miles below the surface.

It will be found, in like manner, that at the depth of 42 miles below the surface, the air would have the same density as quicksilver.

PROBLEM XXXIII.

Of the Air Gun.

This instrument, for the invention of which we are indebted to Otto Guerike, burgomaster of Magdebourg, so celebrated about the middle of the 17th century by his pneumatic experiments, is a machine in which the elasticity of air, violently compressed, is employed to project a ball of lead, in the same manner as gunpowder. It consists of an air chamber, formed by the vacuity between two

cylindric and concentric tubes, placed the one within the other: the bottom of this vacuity communicates with a pump, concealed in the butt end of the gun, and furnished with a piston which serves to introduce and condense the air, by means of valves properly adapted for the purpose. The ball is placed at the bottom of the inner tube, where it is retained by a little wadding, and at the bottom there is an aperture, closed by a valve, which cannot open until a trigger is pulled.

It may now be easily conceived, that when the air in the reservoir or chamber is compressed as much as possible, if the ball be placed at the bottom of the interior tube, and if the trigger, adapted to open the valve which is behind the ball, be pulled, the air violently compressed in the chamber will act upon it, and impel it with a greater or less velocity, according to the time it may have had to exert its action.

To make an air gun then produce the proper effect, it is necessary, 1st. that the opening of the valve should exactly occupy the same time that the ball does to pass through the length of the tube; for during that time the air will accelerate its motion, the expansion of the air being much more rapid than the motion of the ball. If the chamber should remain longer open, it would be a mere loss. 2d. The ball must be perfectly round, and exactly fitted to the calibre of the piece, in order that the air may not escape at its sides. As leaden balls are not always very regular, this defect may be remedied by wrapping a little tow around it.

When these requisites have been attended to, an air gun will discharge a ball with sufficient force to pierce a board two inches in thickness, at the distance of 50, and even of 100 paces. When the air chamber is once filled, it may be employed eight or ten times in succession. An English artist even invented a method of placing these balls in

reserve in a small crooked channel, from which on discharging one ball, another issued to occupy its place; so that a person could discharge the air gun ten times running, much sooner than the most expert Prussian soldier could fire half the number of times. It must however be observed, that the force of the air gun decreases in proportion as the air chamber is emptied.

It may be easily conceived, that if this instrument, instead of being preserved in the cabinets of philosophers, should fall into the hands of certain persons, it would be a most formidable weapon, and the more dangerous as it makes no noise when discharged. But as gunpowder, after being a long time a mere ingredient in artificial fireworks, became the soul of a most destructive instrument, it is not improbable that the air gun, when brought to perfection, may in like manner be employed by armies to destroy each other, gloriously and without remorse.

The air gun is represented pl. 3 fig. 19, where the interval between the two cylinders, which serves to contain the air, may be easily distinguished: MN is the piston, by which the air is introduced into that chamber; TL the valve, by which a communication is formed between the chamber and the cylinder; and O is the trigger. This mechanism may be so easily understood, that no further illustration is necessary.

PROBLEM XXXIV.

Of the Eolipyle.

The Eolipyle is a hollow vessel made of strong metal, and generally in the form of a pear, terminating in a long tail, somewhat bent. It is filled with water or some other liquor, by first exposing it to a strong heat, and then immersing it in the liquor to be introduced into it. While the interior air contracts itself to resume its former volume,

the liquor, in consequence of the pressure of the external air, must necessarily enter to supply its place.

If the eolipyle, when filled in this manner, be placed on burning coals, the water it contains is reduced into vapour, which escapes by the narrow orifice in the tail: or if the fluid, by the position of the eolipyle, presents itself at the entrance, being pressed upon by the vapour, it issues through the orifice with force, and forms a pretty high jet.

If brandy has been employed instead of water, you may set fire to it with a taper; and, instead of a jet of water, you will have the agreeable spectacle of a jet of fire.

This experiment serves to show, in a sensible manner, the strength of the vapour produced by a fluid exposed to a strong heat. For, in the first case, this vapour issues with impetuosity through the orifice of the eolipyle, and in the second the elastic force of the vapour, pressing on the fluid, makes it issue through the same orifice.

This experiment may be rendered still more amusing in the following manner. Provide a sort of small chariot, bearing a spirit of wine lamp, and place the belly of the eolipyle on the latter; close the orifice of the eolipyle with a stopper which does not adhere too firmly, and then kindle the lamp. Some time after, the stopper will fly out, and the fluid or vapour will issue through the orifice with great violence. The chariot being repelled, at the same time, by the resistance which the fluid or vapour experiences from the external air, receives a motion backwards; and if the axle-tree of the wheels be fixed to a vertical axis, the chariot will assume a circular motion, which will continue as long as the eolipyle contains any portion of the fluid.

It may be easily conceived, that this vessel must be made of very strong metal, otherwise it might burst, and either kill or wound the spectators.

PROBLEM XXXV.

To construct small figures, which remain suspended in water, and which may be made to dance and to rise up or sink down, merely by pressing the finger against the orifice of the bottle or jar which contains them.

First construct two small hollow figures of enamel; but in the lower part, representing the feet, leave a small hole, through which a drop of water can be introduced, or apply to the back part of each a sort of appendage in the form of a tail pl. 3 fig. 20, pierced at the end, so that a greater or less quantity of water may be made to enter into this tube. Then bring the figure into equilibrium in such a manner, that with this small drop of water, it shall keep itself upright, and remain suspended in the fluid. Fill the bottle with water to the orifice, and cover it with parchment, which must be closely tied around the neck.

When you are desirous of putting the small figures in motion, press the parchment over the orifice with your finger, and the figures will descend; if you remove your finger they will rise; and if you apply and remove your finger alternately, the figures will be agitated in the middle of the liquor, in such a manner, as to excite the astonishment of those unacquainted with the cause.

The explanation of this phenomenon is as follows. When you press the water through the parchment which covers the orifice of the bottle, the water, being incompressible, condenses the air in the small figure, by causing a little more water, than what it already contains, to enter it. The figure having thus become heavier, must sink to the bottom; but when the finger is removed, the compressed air resumes its former volume, and expels the water introduced by the compression: the small figure, having by these means become lighter, must re-ascend.

PROBLEM XXXVI.

To construct a barometer, which shall indicate the variations of the atmosphere, by means of a small figure that rises or sinks in water.

The principles on which this small, curious barometer is constructed, have been explained in the foregoing problem. For since the pressure of the finger on the water, which contains the small figure in question, makes it descend, and as it rises again when the pressure is removed, it may be easily conceived that the weight of the atmosphere, according as it is greater or less, must produce the same effect. Hence, if the small figure be equipoised in such a manner as to remain suspended during variable weather, it will sink to the bottom when the weather is fine; because the weight of the atmosphere is then more considerable. The contrary will be the case when it threatens rain, and when the mercury in the barometer falls; for the weight of the atmosphere, which rests on the orifice of the bottle, being lessened, the small figure must of course rise.

PROBLEM XXXVII.

To suspend two figures in water, in such a manner that, on pouring in more water, the one shall rise up and the other sink down.

For this purpose, provide salt water, and suspend in it a small figure, or small glass bottle, of such a weight, that if the water contained a little less salt, it would fall to the bottom. Dispose, in the same manner, another small figure or bottle, open at the lower part; so that in the same water it shall keep at the bottom, by the mechanism described in the 35th problem.

When every thing is thus arranged, if fresh water, pretty warm, be poured into the salt water, which con-

tains the figures, the first one will sink to the bottom, in consequence of a cause which may be easily conceived; and at the same time the other will rise to the surface: for the air in the second figure being dilated by the heat of the water, will expel, either in whole or in part, the drop of water which formed a portion of its weight: the figure, having thus become lighter, must consequently rise. These two small figures therefore will change places, merely by the effusion of more water; but the second, when the water cools, will re-descend.

PROBLEM XXXVIII.

Of Prince Rupert's Drops, or Batavian Tears.

This appellation is given to a sort of glass drops, terminating in a long tail, which possess a very singular property; for if you give one of them a pretty smart blow on the belly, it opposes a considerable resistance; but if the smallest bit be broken off from the tail, it immediately bursts into a thousand pieces, and is reduced almost to dust.

These drops are made by letting glass, in a state of fusion, fall drop by drop into a vessel filled with water. They are then found at the bottom completely formed. A great number of them however generally burst in the water, or immediately after they have been taken from it. As these drops were first made in Holland, they are called by the French *Larmes Bataviques.*

Various experiments have been made with these glass drops, to discover the cause of their bursting: these experiments are as follow.

1st. If the tail of one of these drops be broken under the receiver of an air-pump, by a process which may be easily conceived, it bursts in the same manner as it would do in the open air; and if the experiment be performed

in the dark, a flash of light is observed at the moment of rupture.

2d. If the body of one of these drops be ground down gently on a cutler's wheel, or whet-stone, it sometimes bursts; but for the most part it does not.

3d. If a notch be made in the tail, by means of the same stone, the drop will burst.

4th. The tail of one of these drops may be however cut off in the following manner: Present the place, at which you are desirous it should be cut, to an enameller's lamp; by these means it will be fused, and you may then separate the one part from the other, without fear of its bursting.

5th. If one of these drops be carefully heated on burning coals, and if it be then suffered to cool slowly, it will not burst, even when the tail of it is broken.

Philosophers have always been much embarrassed respecting the cause of this extraordinary phenomenon; and it must indeed be confessed that it is still very obscure. We can only say, that it is not produced by air, as is proved by the first experiment. We think ourselves authorised to say also, from the fifth experiment, that it depends on the same cause which makes all articles of glass break, if care has not been taken to anneal them, that is to say, if they are not subjected to a long heat that they may cool gradually, before they are exposed to the contact of the air. This appears to result from the last experiment; but it does not seem clear in what manner it is effected. It arises, in all probability, from the eruption of some fluid in the inside of the drop, which rushes through the broken part of the tail. It is perhaps an electrical phenomenon, and the drop may burst by the same mechanism that often cracks a glass jar, when it is discharged; that is, when the equilibrium is restored between its interior and exterior surface. Having explained the principal phenomena of

these drops, we shall leave the rest to the sagacity and researches of our readers.

PROBLEM XXXIX.

To measure the quantity of rain which falls in the course of a year.

One of the meteorological objects which engage the attention of the modern philosophers, is, to observe the quantity of rain that falls on the earth in the course of a year. This observation may be easily made by means of an instrument, which M. Cotte, in his treatise on Meteorology, calls the *udometer* *, but which, in our opinion, ought rather to be called the *Uometer* †.

This instrument consists of a box of tin plate, or lead or tin, two feet square, which makes four feet of surface. Its sides are six inches in depth at least, and the bottom is a little inclined towards one of the angles, where there is a small pipe furnished with a cock. The water which flows through this pipe, falls into another square vessel, the dimensions of which are much less, and so proportioned, that the height of a line in the large vessel, corresponds to 3 inches in the smaller. In the present case, therefore, the base of this vessel ought to be only 2 inches 6 lines square. From this description it may be easily conceived, that very small portions of a line of water, which has fallen into the large vessel, may be measured; since a line of height in the small one, will correspond to the 36th part of a line in the large one.

If the large vessel be properly placed, with the small one below the cock; and if the small one be covered in such a manner, as to prevent the air from having access to the surface of the water it contains; it will not be necessary

* From ὕδωρ water, and μετρον a measure.

† From υος rain, and μετρον a measure.

to examine the quantity of water which has fallen after each shower, or series of rain. It may be examined and measured every three, or four or five days. It will however be better to do it after each fall of rain.

If a register be then kept of the quantity of water which falls every time that it rains, these quantities added together, will give the quantity that falls in the course of the whole year.

It has been found, in this manner, by a series of observations, made at Paris, for 77 years, that the quantity of rain which falls there, one year with another, is 16 inches 8 lines.

But this quantity of water is not every where the same. In other places it is greater or less, according as they are situated near to the sea or to mountains. The following is a table of the principal places, where observations of this kind have been made, and of the quantity of water which falls there annually.

Places.	Inches.	Lines.
Paris - - - - -	16	8
Bayeux - - - - -	20	0
Beziers - - - -	16	3
Aix in Provence - -	18	5
Toulouse - - -	17	2
Lyons - - - - -	25	0
Lille - - - -	23	0
London - - - - -	18	9
The Hague - - - -	26	6
Rome - - - - -	28	0
Padua - - - - -	30	0
Petersburg - - - -	16	1
Berlin - - - - -	19	6

Remark.—We think it necessary here to offer a remark, which seems to have escaped all the philosophers

who have made observations on the quantity of rain that falls. Every time it again rains, a small quantity of water is lost; namely that which has served to moisten the bottom of the reservoir; for the water does not begin to run down till the bottom is moistened to a certain degree, and covered, as we may say, to a certain thickness with water, the quantity of which must be determined and taken into the account after every fall of rain. This quantity of water may be measured by the following process. Take a small sponge, moistened in such a manner that no water can be squeezed from it, even when pressed very hard; then fill the vessel, and having suffered the water to run from it, collect with the sponge what remains on the bottom, and squeeze it into a vessel, the base of which is an inch square, and already moistened with water. It is evident, that if a vessel, the base of which contains 4 square feet, gives in this manner water sufficient to rise to the height of an inch in the small vessel, there is reason to conclude that the pellicle of water which adhered to the metal was at least $\frac{1}{576}$ of an inch, or the 48th part of a line in thickness. At any rate it may be safely estimated at the 30th or 36th of a line. If it has rained, therefore, two or three hundred times in the course of the year, 8 lines must be added to the quantity found.

PROBLEM XL.

Of the origin of fountains. Calculation of the quantity of rain water sufficient to produce and to maintain them.

It would appear that the origin of fountains and springs ought not to have occasioned such a diversity of opinions, as has, for some time, prevailed among philosophers. An attentive consideration of these phenomena is sufficient to show that the origin of them is entirely owing to the rains which continually moisten the surface of the globe, and which running over beds of earth, capable of preventing

them from penetrating deeper, at length force a passage to places which are lower. Every person indeed must have observed, that the greater part of springs decrease in a considerable degree, when a long drought has prevailed; that some of them absolutely dry up when this drought continues too long; that when the surface of the earth has been moistened with snow or rain, they are renewed, and that they increase almost in the same progression as the waters become more abundant.

Some philosophers however have ascribed the origin of fountains to a sublimation of the waters of the sea, which, flowing into the bowels of the earth, rise up in vapour, in the fissures of the rocks; and thence trickle down into cavities and reservoirs prepared by nature; from which they make their way to the surface. Some have even gone so far as to imagine a sort of subterranean alembics.

But these conjectures are entirely void of foundation. If the water of the sea produced fountains in this manner, it would long ago have choaked up with its salt the subterranean conduits through which it is supposed to pass. Besides, the connection which is observed between the abundance of rain, and that of the water of the greater part of fountains, would not subsist; as the internal distillation would take place whether it rained or not. It is to be observed also, that the water of springs always distils from *above* beds of clay, and not from *below* them; but as these beds intercept the passage of vapours and water, the latter must necessarily come from above them. A sure method of destroying a spring, is to pierce this bed: but if the water came from below, a contrary effect would be produced.

What induced philosophers to have recourse to a cause so remote, and so false, no doubt was, their imagining that rain water was not sufficient to feed all the springs and rivers. But they were certainly in an error: for instead

of rain water being too small in quantity to answer that purpose, it seems rather difficult to conceive in what manner it is expended. This will be proved by the following calculation of Mariotte.

This author observes that, according to experiments which have been made, there falls annually on the surface of the earth about 19 inches of water. But to render his calculation still more convincing, he supposes only 15, which makes per square toise 45 cubic feet, and per square league of 2300 toises in each direction, 238050000 cubic feet.

But the rivers and springs which feed the Seine, before it arrives at the Pont-Royal, at Paris, comprehend an extent of territory, about 60 leagues in length and 50 in breadth, which makes 3000 leagues of superficial content; by which if 238050000 be multiplied, we shall have for product 714150000000, for the cubic feet of water, which falls at the lowest estimation, on the above extent of territory.

Let us now examine the quantity of water annually furnished by the Seine. This river, above the Pont-Royal, when at its mean height, is 400 feet in breadth, and 5 in depth. The velocity of the water, when the river is in this state, may be estimated at 100 feet per minute, taking a mean between the velocity at the surface and that at the bottom. If the product of 400 feet in breadth, by 5 in depth, or 2000 square feet, be multiplied by 100 feet, we shall have 200000 cubic feet, for the quantity of water which passes in a minute through that section of the Seine, above the Pont-Royal. The quantity then in an hour, will be 12000000; in 24 hours 288000000, and in a year 105120000000 cubic feet. But this is not the seventh part of the water which, as above seen, falls on the extent of country that supplies the Seine.

But how shall we dispose of the remainder of this

water? The answer is easy: the rivers, rivulets, and ponds, lose a considerable quantity of water by evaporation; and a prodigious quantity is employed for the nutrition of plants.

Mariotte makes a calculation also of the water which ought to be furnished naturally by a spring that issues a little below the summit of Montmartre, and which is fed by an extent of ground 300 toises in length and 100 in breadth; making a surface of 30000 square toises. At the rate of 18 inches for the annual quantity of rain, the quantity which falls on that extent will amount to 1620000 cubic feet. But a considerable part of this water, perhaps three fourths, immediately runs off: so that no more than 405000 forces its way through the earth and sandy soil, till it meets with a bed of clay at the depth of two or three feet, from which it flows to the mouth of the fountain, and feeds it. If 405000 therefore be divided by 365, the quotient will be 1100 cubic feet of water, which it ought to furnish daily, or about 38500 French pints; which makes about 1600 pints per hour, or 27 pints per minute. Such is nearly the produce of this spring.

An objection founded on an experiment of M. de la Hire, described in the Memoirs of the Academy of Sciences, for the year 1703, is commonly made to this idea respecting the origin of springs. This philosopher having caused a pit to be dug in a field, to the depth of 2 feet, found no traces of moisture; from which some conclude that the rain water flows only over the surface, and does not in any manner contribute to the origin of springs.

But this experiment is of no weight, as it is contradicted by a thousand contrary instances. Every one knows that water, in various places, oozes from the roofs of caverns and subterranean passages: it is this water which, after penetrating the earth, and flowing between the joints of

stones, produces stalactites, and other stony concretions. It is therefore false that rain water never penetrates beyond the depth of a few feet. The fact observed by M. de la Hire was a particular case, from which it was wrong to deduce a general consequence.

It is objected also, that water is sometimes collected at heights at which it is impossible that rain water could give birth to a spring. To this it may be replied, that if the ground, where these collections of water exist, be examined, it will always be found that they are produced by rain or melted snow; that these places on the summits of mountains are only a kind of funnels, which collect the waters of some neighbouring plain, continually maintained by the rain or the snow, assisted by the small evaporation which takes place, in consequence of the rarity of the air. It is therefore evident to every rational mind, that the origin of springs and fountains can be ascribed to no other cause, than the rain water and snow which have been collected.

PROBLEM XLI.

The Water or Mercurial Mallet.

The water mallet, as it is called, is nothing else than a long glass flask containing water, which when shaken in the flask, strikes it with a noise almost like that occasioned by a small blow with a mallet.

The cause of this phenomenon is the absence of the air, for as that fluid no longer divides the water in its fall, it proceeds to the bottom of the flask like a solid body, and produces the sound above mentioned.

To construct the water mallet, provide a long glass flask, pretty strong, and terminating in a neck that can be hermetically sealed; fill one fourth or one fifth of it with water; exhaust the air from it by means of an air-pump, and then close the mouth of the flask hermetically. When

the flask is taken out, if you fuse the neck of it gently at an enameller's lamp, in order to shut it more securely, the instrument will be completed.

If mercury be inclosed in the flask, instead of water, it will make a much greater noise or smarter blow; and you will even be astonished that it does not break the flask. If the mercury be well purified, it will be luminous; so that when made to run from the one end to the other, a beautiful stream of light will be seen in the dark.

Remark.—In our opinion, this property of mercury may be employed to construct what might be called a philosophical lantern. For this purpose, it would be necessary to dispose in a sort of drum a great number of small flasks, like the preceding, or spiral tubes, in which purified mercury should be kept in continual movement; which might be easily done if the drum were made to revolve by means of machinery; the result would be a continued light, which would have no need of aliment, or of being fed. Who knows, whether this idea may not enable us, at some future period, to dispense with the candles and lamps which we now employ to light our apartments? We are however afraid, that whatever be the number of flasks arranged in this manner, they will still afford too weak a light to supply the want of a single taper. But, perhaps, there are other useful purposes to which this invention may be applied.

PROBLEM XLII.

To make a Luminous Shower with Mercury.

Place on the top of the air-pump a small circular plate, pierced with holes, and supporting a small cylindric receiver, terminating in a hemisphere; and cover the whole with a larger receiver, having a hole in its summit, capable of admitting a glass funnel filled with mercury. This funnel must be so arranged, that it can be shut with a

stopper, so as to be opened when necessary. Then exhaust the air, or nearly so, from the receiver, and open the funnel which contains the mercury: the mercury, in consequence of its weight, and of the pressure of the atmosphere, will run down, and, falling on the convex summit of the interior receiver, will be thrown up in small luminous drops, so as to resemble a shower of fire.

This experiment may be performed also in the following manner: provide a piece of pretty compact wood, and cut in it a small reservoir in the shape of a hemisphere, or of an inverted cone: apply it to the upper aperture of a receiver, and fill it with mercury. If you then exhaust the receiver, the pressure of the external air will force the mercury through the pores of the wood, so that it will fall down in small luminous drops.

PROBLEM XLIII.

What is the reason that in mines, which have spiracles, or air-holes, on the declivity of a mountain, at various heights, a current of air is established, which in winter has a direction different from what it has in summer? Explanation of a similar phenomenon, observed daily in chimneys.—Use to which a chimney may be applied in summer.

It is customary, in order to introduce air into a mine, at certain distances to sink perpendicular wells, which terminate at the horizontal or somewhat inclined gallery, where the ore is dug up; and, in general, the mouths of these wells are at different heights, in consequence of the inclination of the side of the mountain. But, in this case, a very singular phenomenon is observed: during the winter the air rushes into the mine through the mouth of the lowest well, and issues by that of the highest; the contrary is the case in summer.

To explain this phenomenon, it must be observed, that in the mine, the temperature of the air is constantly the

same, while without, it is alternately colder and hotter; that is, colder in winter, and warmer in summer. It is to be remarked, on the other hand, that the well which has the mouth highest, the gallery, and the other well, form all together a bent syphon with unequal branches: the effect produced is as follows:

When the exterior air is colder than that in the mine, the column of air which presses on the lower orifice D, pl. 4, fig. 21, exerts a greater pressure on the whole air contained in the syphon DCBA, than that which presses on the upper orifice A; this air then must be expelled by circulating in the direction DCBA. But the cold air which enters by D, being immediately heated to the same degree as that in the mine, is impelled, like the former, by the column which rests on the orifice D.

The contrary takes place in summer; for the exterior air, during that period, is warmer than the air in the mine. The latter then being heavier, that contained in the branch AB of the syphon, preponderates over the air in BC; so that the difference between the columns, which press upon A and D, is not able to produce a counterpoise. The air contained in the syphon ABCD then must receive an impulse in that direction; and consequently must move in a direction contrary to the former. Such is the explanation of this phenomenon.

A similar one is observed daily in chimneys; and it is the more sensible, as the flues of the chimneys are higher; for a chimney, with the chamber where it terminates, and the door or a window, form a syphon, similar to the preceding. Besides, the exterior air from nine in the morning till eight or nine at night, in summer, is warmer than the interior, and vice versa. In the morning then, the air must descend the chimney, and issue through the door or the window; on the other hand, as the exterior air is colder in the night than in the day, it must, during the

former, enter at the door or window, and ascend the chimney. About eight or nine in the morning, and at eight or nine in the evening, the air is, as it were, stationary: an effect which must necessarily take place at the time of the passage from one direction to another.

Dr. Franklin, who seems to have first observed this phenomenon, says that it might be applied to some economical uses during summer; and in that case the proverb, *as useless as a chimney in summer*, would not be correct. One of these uses is, that the chimney might be employed as a safe; for if each of its mouths were closed by a piece of canvas, stretched on a frame, the alternate and almost continual current of air which would be established in it, could not fail to preserve meat from corruption.

This current might perhaps be employed also for some work that requires not so much a force, as a continuance of it. For this purpose, it would be necessary to fix in the flue of the chimney a vertical axis with a helix, like the fly of a smoke-jack; the current of air would keep it in continual motion, sometimes in one direction, sometimes in the other; and in all probability with sufficient force to raise a small quantity of water per hour. And, as it would remain inactive only three or four hours a day, it could not fail to produce a considerable effect daily. Besides, the moving power would cost nothing. It would however be necessary to have the wheels adjusted in such a manner, that to whatever side the axis, furnished with the helix, turned, the machine should always move in the same direction; which is not only possible, but was executed by M. Loriot at Paris.

Remark.—The same effect is easily experienced on a small scale, in a close room or chamber, which is very warm with several persons and candles in it, especially if there is no fire or no fire-place. For, by unlatching the door, and setting it a very little open, as an inch or half an inch, it

will then be found that the air rushes strongly in near the bottom, but sets as strongly out near the top, and is quiescent near the middle parts. This is very easily tried by holding a candle in your hand, first near the bottom of the small opening, where the flame is violently blown inwards; then at the top, where it is carried strongly outwards; but held near the middle, the flame of the candle is quite still.

PROBLEM XLIV.

To measure the height of mountains by the barometer.

It is very difficult, and even sometimes impracticable, to measure the height of mountains by geometrical operations. A traveller, for example, who traverses a chain of mountains, and who is desirous of ascertaining the altitude of the principal points he has ascended, cannot have recourse to that method. The barometer however supplies a convenient and pretty exact one, provided it be employed with the necessary attention.

The principle on which this method is founded will be readily conceived, when it is recollected that if a barometer be carried to the top of a mountain, the quicksilver stands at a less height than at the bottom. 1st. Because it has a less column of air above it. 2d. Because this air has less density, as it is freed from the weight of a part of the air which it supported at the bottom of the mountain. Such is the foundation of the rules which have been invented for applying the height at which the mercury in the barometer stands to the purpose of measuring the height of mountains. But to give a very exact rule in regard to this operation, is attended with no small difficulty; for the height of the mercury in the barometer depends on a complication of so many physical causes, that it is exceedingly troublesome to reconcile them, and to subject them to calculation. M. de Luc of Genéva, who has considered this

subject with the greatest care, by combining all these causes and circumstances, seems to have discovered a method which, if not absolutely perfect, is certainly more correct than any before given.

To proceed with exactness in this operation, it is necessary to have a good portable barometer, well freed from air; and a good thermometer, which we shall suppose to be that of Reaumur, though M. de Luc, to facilitate the calculation, proposes a particular kind of division. If great correctness be required, it will be necessary also that an observer should examine the progress of the barometer at the bottom of the mountain, or in one of the nearest towns, the height of which above the level of the sea is known.

When you have reached the summit of the mountain, or the place the altitude of which you are desirous of ascertaining, hold the barometer in a direction perfectly vertical, and examine the height of the mercury; suspend also the thermometer in some insulated place in the neighbourhood, and observe the degree to which the mercury rises.

Having then compared the height of the barometer observed on the mountain, with that of the corresponding barometer, observed at the same time at the bottom, take the logarithms of these two heights, expressed in lines, and cut off from them the four last figures: the remainder will be the difference of the heights expressed in French toises.

But this altitude requires a correction; for it is only exact when the simultaneous temperature of the two places is $16\frac{3}{4}$, according to the scale of Reaumur's thermometer. For each degree then that the thermometer has remained below $16\frac{3}{4}$, at the upper station, one toise must be added for every 215, and the same must be deducted for every degree above that temperature.

The same correction *, but in the contrary sense, must be made by means of the thermometer left at the fixed station; that is to say, for each degree it remained above 16¼, one toise in 215 must be deducted, and vice versa. The height, when twice corrected in this manner, will be the difference nearly between the height of the two places above the surface of the sea, or the height of the one above the other.

Let us suppose, for example, that at the lower station the barometer stood at the height of 27 inches 2 lines, or 326 lines; and that at the upper station it fell to 23 inches 5 lines, or 281 lines.

The logarithm of 326 is 2·5132176, and that of 281 is 2·4487063; their difference is 0·0645113; from which if the three last figures be cut off, to answer for division by 1000, the remainder will be 645 toises.

We shall suppose also, that at the top of the mountain Reaumur's thermometer stood at 6 degrees above freezing, and in the lower station at 12; that is for the former 10¼ below 16¼, consequently 10¼ toises are to be added to the above number for every 215; and hence, by the rule of three, the number to be added will be found to be 32 toises.

It will be found, by the converse correction, that the height to be deducted is 20; consequently there will remain 12 toises to be added, and therefore the height twice corrected will be 657.

Mr. Needham, on mount Tourné, one of the Alps, observed the height of the barometer to be 18 inches 9 lines, or 225 lines. Now if we suppose that it was observed at the same moment at the level of the sea to stand exactly at 28 inches or 336 lines, which is its mean height on the borders of the sea, the difference between the logarithm of

* This second correction, though not mentioned by M. de Luc, appears to us necessary, for several reasons, which it would be too tedious to explain here.

336 and that of 225, cutting off the last three figures, will be found to be 1742. It may therefore be concluded, that the height of mount Tourné is 1742 toises. But as in this case we have no corresponding observation at the level of the sea, nor any observation of the thermometer made at the same time, we have employed this observation of Needham only as an example of calculation. It is however probable that the height of mount Tourné is between 1700 and 1800 toises.

REMARKS.—As a portable barometer is an instrument difficult to be procured and preserved, it is almost necessary that a traveller, when he is desirous of making observations, should construct a barometer for himself; but in this case, as the mercury will not be freed from air, it will always stand a few lines lower than a barometer which has been constructed with every possible care. This difference may amount to two or three lines.

In regard to Reaumur's thermometer, it is easily carried; but in what manner must a traveller proceed to have corresponding observations, either on the borders of the sea, or in any other determinate place, which are necessary before he can employ his own with sufficient exactness? This difficulty, in our opinion, seems to limit, in a considerable degree, this method of determining the height of mountains.

Besides, it appears that, even if a traveller had on the borders of the sea, or in any village situated for example in the centre of France, the height of which above the sea is known, a diligent observer, he would not be much farther advanced, for the temperature of the atmosphere may be different on the borders of the sea at Genoa, that is to say, it may rain, for example, while the weather is fine and serene on the Alps or the Appenines; or the contrary may be the case; and hence there is a new difficulty to be surmounted.

This difficulty however might be obviated in part, by knowing the greatest, the mean, and the least elevation, of the barometer on the borders of the nearest sea, and thence determining, by meteorological conjectures, the nature of the temperature on the mountain to be measured, though one only passed over it: thus, if an hygrometer on the mountain indicated, for example, great moisture, there would be reason to conclude that the weather was inclined to rain, and that the fixed barometer stood at its least height. On the other hand, if the air was very dry, it might with probability be concluded that the weather was serene, and that the fixed barometer stood at its greatest height; but it must be confessed that this is not sufficient to give a satisfactory exactness.

However, a great many barometrical observations have been made on the summits of mountains, and their heights have been thence deduced. Several of them have also been measured geometrically, and therefore we flatter ourselves that the following table, of these observations and heights, will be gratifying to many of our readers. It consists of four columns; the first of which needs no explanation; the second contains the height of the barometer as observed at the different places enumerated in the first. As the temperature of the air at the time is not mentioned, we shall take that height as the mean height, and at the mean degree of heat. The third column contains the height as deduced from observation, according to the method of M. de Luc. In the fourth column we have placed the geometrical measurement, when known, and sometimes also we have given it alone, because we could find no other.

We shall not repeat here what has been already said in regard to the immoderate height which the ancients ascribed to some mountains. The reader will find it in the preceding volume, page 102.

TABLE *of the heights of different places of the earth, and of various mountains, above the level of the sea.*

NAMES OF PLACES.	Height of the Barometer.		Height deduced from the Barometer.	Height measured Geometrically.
	Inc.	Li.	Toises.	Toises.
FRANCE.				
Paris, level of the Seine when the water is at a mean height at the Pont-Royal	—		—	48½
Paris, level of the site of the observatory	—		—	58
Versailles, site of the castle . .	—		—	77½
Orleans, level of the Loire . .	—		—	52
Lyons, level of the Rhone . .	—		—	84
Clermont-Ferrand . . .	27	0½	158	—
Mountains of Auvergne.				
The Puy-de-Dome . . .	23	9½	716	—
The Costa	23	4	825	851
The Puy-de-Violent . . .	23	3	840	853
The Cantal	22	5	966	984
Mont d'Or	22	1	1031	1040
Pyrenées.				
Mont St. Barth in the Pays de Foix	21	2⅓	1211	1190
The Mousset	21	0⅔	1241	1289
The Canigou	20	2½	1416	1454
Bains de Barege	24	8	589	—
Le Pic du Midi	21	1	1481	—
Mount Ventoux	—		—	1036
Swiss Alps.				
The Lake of Geneva . . .	—		—	188
Lake of Neuchatel . . .	—		—	214
The Glacier of Buet near Geneva .	19	6	1560	—
The Mountain of La Dole near ditto	23	4	825	847
Mount Blanc, or Maudit in Faucigny	—		—	2390
Fort d'Aarbourg . . .	—		—	237
Mount Pilate in the Canton of Lucerne	—		—	1450
L'Antesendas, in the Canton of Berne	—		—	1460

Names of Places.	Height of the Barometer.		Height deduced from the Barometer.	Height measured Geometrically.
	Inc.	Li.	Toises.	Toises.
Mount Gothard, highest point* .	—		—	2420
Appenines.				
Mount di Sibilla	—		—	1150
——— di Carpegna . . .	—		—	718
——— di Catria	—		—	868
——— di Pennino . . .	—		—	808
Piedmontine Alps.				
Turin	27		123	—
St. Remi	23		854	—
Mount St. Bernard, at the convent	20	10	1254	—
Mount Serene	20	7	1328	—
Cor-Mayeur at the summit of the White Alley	20	9	1302	—
Ville des Glacieres . . .	22	6½	942	—
Mine de Pesey in Savoy . .	21	10	1080	—
Mount Tourné	18	9	1742	—
Sicily.				
Mount Ætna †	18	1½	1676	—
Canaries.				
Peak of Teneriffe . . .	17	5	1980	—
Peru.				
The valley of Quito, at Quito the capital of that province . .	20	1	—	1470
Pitchintcha, extinguished volcano, eastern summit . . .	15	11	2453	2434
Antisana, extinguished volcano .	—		—	3020
El Coraçon	15	10	2496	2470
Ilinica	—		—	2727

* This mountain seems to be the highest in Europe. I deduced the height of it from the apparent height measured by M. Micheli from fort Aarbourg, which is 6200 toises. But as this height is only equal to two degrees above the horizon, I corrected it by deducting the refraction: as M. Micheli did not attend to this point, he has given a list of the mountains in Swisserland with their heights, which certainly exceed the truth.

† This measurement is deduced from simultaneous observations of the barometer made at Catanea, where the mercury was at 27 in. 10 lin. French, and on Ætna, where it was at 18 in. 1½ lin. Attention was paid also, according to M. de Luc's rule, to the different temperatures of the air, which were on Ætna 2¼ of Reaumur's thermometer, and at Catanea 19¾.

Names of Places.	Height of the Barometer.	Height deduced from the Barometer.	Height measured Geometrically.
	Inc. Li.	Toises.	Toises.
Cotopaxi volcano, rekindled in 1744	—	—	2950
Chimboraço, extinguished volcano	—	—	3220
Cargaviraço, ditto . . .	—	—	2430
Tongouragoa, ditto . . .	—	—	2620
El-Altar, ditto	—	—	2730
Sangai, ditto	—	—	2680
Cota-Catché, north of Quito .	—	—	2570
Cayambé-Orcou, under the equator	—	—	3030
Africa.			
Table mountain	24 10	521	537

GENERAL OBSERVATION.

We shall here remark, that the very considerable differences often found in the above table, between the barometric and geometrical measurement, must not be entirely imputed to the method. The latter is certain; but the observers of the barometrical heights have often employed imperfect instruments: in general, they have had no corresponding observations; and they have scarcely ever taken into account the difference of temperature at the posts of comparison: these differences, which without these defects in the observations would have certainly been less, need therefore excite no astonishment.

Remark.—In the above table, the height of the barometer is given in French inches and lines, and the corresponding heights of the mountains in French toises. We must observe also, that the French, in general, consider 28 Paris inches as the mean height of the barometer, at the level of the sea: as the following remarks on this subject by Mr. Kirwan, may be of use to the reader, we here subjoin them. " Sir George Schuckburgh has shown, from 132 observations, made in Italy and in England, that

the mean height of the barometer at the level of the sea, the temperature of the mercury being 55°, and of the air 62°, is 30·04 inches*, we may then assume the height of 30 inches as the natural mean height of the barometer at the level of the sea, in most temperatures between 32° and 82°; for if mercury were cooled down to 32°, that is 23° below 55°, it would be lowered by that condensation only 0·07 of an inch, and if it were heated up to 80°, that is 25° above 55°, it would be raised only ·078 of an inch; quantities which, except in levelling, may be safely disregarded.

"The French have heretofore considered 28 Paris inches as the mean height of the barometer at the level of the sea, that is 29·84 English inches. But from 1400 observations, made at Rochelle by Fleurieu de Bellevue, and from five years' observations made at Port Louis, in the isle of France, he concludes the mean height of the barometer at the level of the sea to be 28 inches and 2 lines and $\frac{10}{12}$ of a line, in the temperatures of from 52° to 55° Fahrenheit, or 30·08 English inches†. Hence we may consider, in round numbers, 30 inches as the standard height of barometers at the level of the sea. And knowing the true height of any part of the earth, we may, by subtracting that height, expressed in fathoms, from the log. of 30, viz, 4771·213, find the logarithm which indicates the number of inches at which, as its natural mean, the mercury should stand at that height above the level of the sea.

"Thus, supposing the height to be 87 feet, equal to 14·500 fathoms; then 4771·213 – 14·500=4756·713, which is the logarithm of 29·9; this therefore is the natural mean height of the barometer at the elevation of 87 feet above the level of the sea.

"Consequently, to all heights heretofore calculated by

* Phil. Transact. 1777, p. 586.

† La Chappe thought it 28 inches 1·5 lines. See Beguelin's Mem. Berl. 1769. ·12 Coll. Acad, 424.

the French, above the level of the sea, 139·32 feet must be added English measure, when the mercurial height at the level of the sea was barely supposed to be 28 French inches." *On the Variation of the Atmosphere,* by Richard Kirwan, esq. L.L.D. F.R.S. and P.R.I.A. Dublin 1801.

ADDITIONAL TABLE *of the height of Mountains from Von Zach's Geographische Ephemeriden.*

	Toises.
Ophir in Sumatra under the equator, according to Marsden 13842 feet	2307
Aiguille d'Argenture, according to Saussure	2094
Corne du Midi, according to De Luc	1945
Peak of Teneriffe, according to Borda	1904
Maladetta and Mont Perdu, in the Pyrenées	1763
Vignemale, in ditto	1722
Mount Tourne, in Savoy	1683
Ætna, according to Saussure	1672
Pic Long, in the Pyrenées	1668
The summit of Marboré, in ditto	1636
Buet, according to Saussure	1579
Monte Rotondo, in Corsica	1549
Mount Libanon	1500
Summit of Mount St. Gothard	1431
The Canigou, in the Pyrenées, according to Mechain	1427
The Budislaw, in Transylvania	1148
The Monastery of the Capuchins, on Mount St. Gothard	1105
The Surut, in Transylvania, according to Lerchenfeld	1078
Mount d'Or in Auvergne, according to Cassini	1048

Swiss Alps, height above the Thuner Lake, according to Professor Tralles of Berne.

Finsterahorn	1908
Jungfrau	1844

	Toises.
Monch	1813
Eiger	1747
Wetterhorn	1611
Niesten	925
Stockhorn	830
Elleborus, in Caucasus	904
Kschoes, on the banks of the river Kur . .	895
The Schnukoppe, in the Riesengebirge . .	820
Puy de Dome, according to Cassini . . .	817
Vesuvius, according to Saussure . . .	650
The Fichtelberg, in Franconia	603
The Feldberg, in Schwarzwald, near Freybourg	563
The Brocken, in the Harse	546
Rupberg, in Henneberg	520
The Schneekopf in Thuringia	503
The Inselsberg in the principality of Gotha .	472

Rule to compute heights by the Barometrical English measures.

To complete the foregoing account of the measurement of altitudes by the barometer, I shall here annex the method of performing that operation in English measures, either feet or fathoms, as extracted from my Philos. Dict. article Barometer, or from my Course of Mathematics, vol. 2, pa. 255, edit. 6; which is as follows.

1. Observe the degree or height of the barometer, both at the bottom and top of the hill, or other place, the altitude of which is required, as also the degree of the thermometer, for the temperature of the air, in both the same places.

2. Take out, from a table of logarithms, the logs. of these two heights of the barometer in inches and parts, and subtract the less log. from the greater. If from the remainder there be cut off three figures on the right hand,

where the logs. consist of seven places, the other figures on the left hand will give the altitude required in fathoms, of 6 feet each.

3, The above result requires a small correction, when the medium temperature of the air is different from 31 degrees on Fahrenheit's thermometer, which may be thus found, when much accuracy is desired. Add the two observed heights of the thermometer together, and take half that sum for the mean temper of the air. Take the difference between this mean and the number or temper 31; then, as many units as this difference amounts to, take so many times the 435th part of the fathoms above found; to which add them when the mean temperature exceeds 31, but subtract them when it is less; and the result will be the more correct altitude of the hill, &c, as required.

A small correction for the temperature of the barometer is sometimes employed, as may be seen in the books above quoted; but it is so small as to be seldom necessary to be observed.

For example, suppose at the foot of a mountain, the barometer be observed 29·68 inches, and the thermometer 57; at the same time at the top of the mountain the barometer was 25·28, and thermometer 42. Then the calculation will be as below.

29·68 log. 4724639	57
25·28 log. 4027771	42
696·868	2) 99
or 697 nearly.	49½ mean
	31 subtr.
	18½

then, as 435 : 18½ : : 697 : 29 the correction.
29

726 fathoms = 4356. f.

So that the required altitude is equal to 726 fathoms, or 4356 feet.

PROBLEM XLV.

To make an Artificial Fountain, which shall imitate a natural spring.

We here suppose that those who intend to try this experiment, have at their command a piece of ground, somewhat inclined, the bottom of which is a bed of clay, not far distant below the surface of the earth. In this case, a spring absolutely similar to a natural one, and capable of answering every domestic purpose, may be constructed by the following process.

Uncover this bed of clay for the extent of an acre, or about 70 yards in length, and the same in breadth. A border of clay must be formed at the lower end, leaving only one aperture at the lowest point, through which the water may issue. To this aperture adapt a stone with a hole in it, about an inch in diameter. Then collect pebbles of various sizes, and cover this area with the largest, leaving an interval of a few inches only between them. Place others, somewhat smaller, above the interstices left by the former; arranging several strata in this manner above each other, always diminishing the size, till the last are only very large gravel. Cover the whole, to the thickness of some inches, with coarse sand, and then with some that is finer; but if moss can be procured, it will be proper to cover the very large gravel with it to the thickness of half an inch, to prevent the sand from falling into the interstices between the pebbles.

It is evident that the rain water, which falls on the surface of this area, will penetrate through the sand, flow into the interstices between the pebbles, which cover the bed of clay, and at last, in consequence of the inclination of the ground, will proceed towards the aperture at the

bottom, through which it will issue in a stream of greater or less size, according to the abundance of the rain.

Now, if we suppose that the water which falls annually on this piece of ground is 18 inches in height, it will be found that the quantity of water collected, will be 66150 cubic feet; and if we suppose one fourth wasted by evaporation, or remaining between the joints and interstices of the stones, sand and moss, we shall still have about 49600 cubic feet of water in the year, or about 303800 gallons; that is to say, almost 1000 gallons per day, a quantity much more than is necessary for the largest family.

It will perhaps be said, that such a spring of water would cost exceedingly dear. This we shall admit. But we much doubt whether the construction of it would cost so much as that of a large cistern, which, to confine the water, requires to be lined with clay or cement: besides, the water collected by a cistern, is only the rain water which falls from the roofs of a few houses, and which is consequently impure.

Besides, it might be rendered much less expensive by preparing, in the above manner, a small portion of ground, such as twenty yards square; and, to increase the quantity of rain water thus obtained, which would not exceed 5400 cubic feet, that which fell on the neighbouring ground might be conveyed thither by small drains, from the distance of some hundred yards. By these means, a very abundant reservoir of filtred water might be formed at a very small expence; and the proprietor would enjoy the pleasure of having a spring, exactly similar to those furnished by nature.

We are only apprehensive that the water would flow off with too much rapidity; but this inconvenience might be prevented by making the aperture through which it escaped of such a size as to render it perpetual; or by

adapting to it a cock, and keeping it shut till it might be necessary to draw water.

PROBLEM XLVI.

What is the weight of the air with which the body of a man is continually loaded?

Who would imagine that the human body is continually loaded with the weight of twenty or thirty thousand pounds, which compresses it in every direction? This, however, is a truth which has been placed beyond all doubt by the discovery of the gravity of the air.

Every fluid presses on its base, in the ratio of the extent of that base, and of its height. But, it has been proved, that the weight of the air is equivalent to the weight of a column of water 32 feet in height; consequently every square foot, at the surface of the earth, is charged with a column of air equal to one of water of 32 cubic feet; that is to say 2000 pounds, as a cubic foot of water weighs 62 pounds and a half. The surface of the body in a man of moderate size is estimated at 14 square feet; and therefore, if 2000 be multiplied by 14, we shall have 28000 pounds for the weight applied to the surface of the body of a moderate sized man.

But, how is it possible to withstand such a load? The answer is easy: the whole human frame is filled with air, which is in equilibrium with the exterior air. Of this there can be no doubt; for an animal placed under the receiver of an air pump, swells up as soon as the machine begins to be evacuated of air; and if the operation be continued, it will distend so much that it will at length perish, and even burst.

It is the difference of this gravity that renders us more active or oppressed, according as the body is more or less loaded. In the first case, the body being more contracted by the weight of the air, the blood circulates with greater

rapidity; and all the animal functions are performed with more ease. In the second, the weight being diminished, the whole machine is relaxed, and the orifices of the vessels become relaxed also; the motion of the blood is more sluggish, and no longer communicates the same activity to the nervous fluid; we are dejected, and incapable of labour, as well as of reflection, and this is the case in particular when the air is at the same time damp; for nothing relaxes the fibres of our frail machine so much as moisture.

PROBLEM XLVII.

Method of constructing a small machine, which, like the statue of Memnon, shall emit sounds at sun-rise.

The story respecting the statue of Memnon, exhibited in one of the temples of Egypt, is well known. If we can credit the ancient historians, it saluted the rising sun by sounds, which seemed to proceed from its mouth. But however this may be, a similar effect can be produced in the following manner.

Provide a pedestal, in the form of a hollow parallelopipedon ABC, pl. 4, fig. 22; and let the cavity be divided into two parts, by a partition DE. The lower part must be very close, and filled with water to a third of its height: the remainder must be filled with air. The partition DE must have a hole in it to receive a pipe, some lines in diameter, well soldered into it, and which reaches nearly to the bottom of the lower cavity. This tube must contain such a quantity of water, that when the air is cooled to the temperature of night, the water shall be nearly at the level of FG. One of the faces of the pedestal must be so thin, as to become easily heated by the rays of the sun. Of all metals, lead is the soonest heated in this manner; and therefore a thin plate of lead will be very proper for the required purpose.

KL is an axis, which revolves freely on its pivots at K and L; round this axis is rolled a very flexible cord, which supports on the one hand the weight N, and on the other the weight M, which moves freely in the pipe HI. The ratio of these weights must be such, that M shall preponderate over N, when the former is left to itself; but N must preponderate when the former loses a part of its weight by floating in the water; this combination will not be attended with much difficulty.

In the last place, the axis KL supports a barrel, some inches in diameter, and a few inches in length, implanted with spikes, which, touching keys like those of a harpsichord, raise up quills and make them strike against strings, properly attuned. The air must be finished in one or two revolutions of the barrel, and it must be exceedingly simple, and consist of a few notes only. All this mechanism may be easily inclosed in the upper cavity of the pedestal. On the top of it must be placed a figure or bust, representing that of Memnon, with its mouth open, and in the attitude of speaking. It would not be difficult to connect its eyes with the axis KL, in such a manner as to render them moveable.

From this description it may be readily conceived, that the side of the pedestal, exposed to the east, cannot receive the rays of the sun without becoming hot; and that, when heated, it will heat the air contained in the lower cavity; this air will make the water rise in the pipe HI, by which means the weight N will preponderate, and cause the axis KL to revolve, and consequently the cylinder furnished with spikes, which will raise the keys; and in this manner the air that has been noted will be performed. But for this purpose the diameter of the axis KL must be so proportioned, that the weight N by descending, two lines for example, shall cause the cylinder to revolve once or twice

with sufficient rapidity, to make the sounds succeed each other quick enough to form an air.

Father Kircher, it is said, had in his Museum a machine nearly of the same kind; a description of which has been given by Father Schott; but we think ourselves authorized to assert, that it could not produce the desired effect; for Schott says that the air was impelled through a small pipe against a kind of vanes, implanted in a small wheel; but as the air, in this manner, could issue only very slowly, it is evident that no motion could be communicated to the wheel. If Kircher's machine then produced any effect, as said, the mechanism of it has not been properly described by Schott. We will not venture however to assert, that the one in question will answer the intended purpose, as we much doubt whether the rising sun would rarefy the air, contained in its lower cavity, in a manner sufficiently sensible in all climates.

Remark.—We shall say nothing farther in regard to machines which may be put in motion by the compression, or the rarefaction, or condensation, &c, of the air; for if we should imitate Father Schott, we might find sufficient matter to fill a quarto volume. We shall therefore refer those who are fond of such machines to the *Mecanica hydraulico-pneumatica* of that Jesuit, printed at Frankfort in 1657, 4to; and to his *Technica curiosa* or *Mirabilia Artis.* Herbip. 1664, 2 vols. 4to.

The reader will find in these books abundance of such frivolous inventions, extracted for the most part from the works of Father Kircher, who paid a good deal of attention to them; and from the *Spiritalia* of Hero; and from Alleoti his translator and commentator; as also the *Philosophia Fontium*, of Dobrezensky, &c, &c.

PROBLEM XLVIII.

The phenomena of Capillary Tubes.

Capillary tubes are tubes of glass, the interior aperture of which is very narrow, being only half a line, or less, in diameter. The reason of this denomination may be readily perceived.

These tubes are attended with some singular phenomena, in the explanation of which, philosophers do not seem to have agreed. Hitherto it has been easier, in this respect, to destroy, than to build up. The principal of these phenomena are as follow:

I. It is well known that water, or any other fluid, rises to the same height in two tubes which have a communication with each other; but if one of the branches be capillary, this rule does not hold good: the water in the capillary tube rises above the level of that in the other branch, and the more so, the narrower the capillary tube is.

It seemed very easy to the first philosophers, who beheld this phenomenon, to give an explanation of it. They supposed that the air, which presses on the water in the capillary tube, experiences some difficulty in exercising its action, on account of the narrowness of the tube; and that the result must be an elevation of the fluid on that side.

This however was not very satisfactory; for what reason is there to think that the air, the particles of which are so minute, will not be at perfect freedom in a tube half a line, or a quarter of a line, in diameter?

But whether this explanation be satisfactory or not, it is entirely overturned by the second and third phenomena of capillary tubes.

II. When mercury is employed, instead of water, this fluid, instead of rising in the capillary branch, to the

level which it reaches in the other, remains below that level.

III. If the experiment be performed in vacuo, every thing takes place the same as in the open air. The cause of this phenomenon then is not to be sought for in the air.

IV. If the inside of the tube be rubbed with any greasy matter, such as tallow, the water, instead of rising above the level, remains below it. The case is the same, if the experiment be made with a tube of wax, or the quills of a bird, the inside of which is always greasy.

V. If the end of a capillary tube be immersed in water, this fluid immediately rises above the level of that in the vessel, and to the same height to which it would rise in a syphon, if one of its branches were a capillary tube, and the other of the common size; so that if the surface of the water only be touched, it is immediately attracted, as it were, to the height above mentioned, and it remains suspended at that height when the tube is removed from the water.

VI. If a capillary tube be held in a perpendicular direction, or nearly so, and if a drop of water be made to run along its exterior surface, when the drop reaches its lower aperture, it enters the tube, if it be of sufficient size, and rises to the height at which it would stand, above the level, in the branch of a syphon of that calibre.

VII. The heights at which water maintains itself in capillary tubes, are in the inverse ratio of the diameters. Thus, if water rises to the height of 10 lines in a tube one 3d of a line in diameter, it ought to rise to the height of 20 lines in a tube one 6th of a line in diameter, and to the height of 100 in a tube one 30th of a line in diameter.

The falling of mercury below the level in such tubes, follows also the inverse ratio of the diameters of the tubes.

VIII. If a capillary tube be formed of two parts of un-

equal calibres, as seen pl. 4, fig. 23, where the diameter of AB is much less than that of BC, and if *ab* be the height at which the water would maintain itself in a tube such as AB, and *cd* that at which it would remain in the larger one BC, when this tube is immersed in such a manner that the aperture of the smaller end B, shall be raised above the level, by a height greater than *cd*, the water will maintain itself as seen fig. 24, at that height *cd* above the level: but if the tube be immersed in such a manner that the water shall reach to B, it will immediately rise to the same height as if the tube were of the same calibre as that before mentioned.

The case is the same, if the capillary tube be immersed, beginning with the narrower branch.

IX. Those persons would be deceived who should imagine, that the lightest liquors rise to the greatest height in these tubes: of aqueous liquors, spirit of wine is that which rises to the least height. In a tube in which water rises 26 lines, spirit of wine rises only 9 or 10. The elevation of spirit of wine, in general, is only the half or a third of that of water.

This elevation depends also on the nature of the glass: in certain tubes, water rises higher than in others, though their calibres be the same.

To be convinced that these effects are not produced by any thing without the tube or the liquor, it is necessary to see these phenomena, which are indeed the same in a vacuum, or in air highly rarefied, as in the air which we breathe. They vary also according to the nature of the glass of which the tube is formed; and they are different according to the nature of the fluid. The causes therefore must be sought for in something inherent in the nature of the tube, and in that of the fluid.

This cause is generally ascribed to the attraction mutually exercised between glass and water. This ex-

planation has been controverted by Father Gerdil, a Barnabite and an able philosopher, who has done every thing in his power to overturn it. On the other hand, M. Lalande has stood forth in its defence, and is one of those modern writers who have placed this explanation in the clearest light. The reader may consult also, on this subject, a very learned and profound memoir by M. Weitbrecht, in the Memoirs of the Imperial Academy of Sciences at Petersburg.

PROBLEM XLIX.

Of some attempts to produce a Perpetual Motion, by means of capillary siphons.

When philosophers saw water rise in a capillary tube, above the level of that in which it was immersed, or above that at which it stood in a wider tube, with which is formed an inverted siphon, they were induced to conjecture the possibility of a perpetual motion; for if the water, said they, rises to the height of an inch above that level, let us interrupt its ascent, by making the tube only three quarters of an inch in height: the water will then rise above the orifice, and falling down the sides into the vessel, the same quantity will again rise, and so on in succession. Or, if the water that rises in the capillary branch of a siphon be conveyed, by an inclined tube, into the other branch, a continual circulation of the fluid will take place; and hence a perpetual motion given by nature.

But, unfortunately, this idea was not confirmed by experiment. If the ascent of water, in a capillary tube, be intercepted, by cutting the tube at half the height, for example, to which the water ought to rise, the latter will not rise above the orifice to trickle down the sides. And the case will be the same in the other attempt.

The following, however, is a very ingenious one; and it is difficult to discover the cause of its not succeeding.

Let ABC, pl. 4, fig. 25, be a capillary tube, the diameter of the long branch of which is much smaller than that of the other: it is supposed, that if the orifice A be immersed in the water contained in the vessel DE, it will rise to B, the summit of the bending of the tube; and that in the other branch BC, it will rise only to the height CH above the level.

If the siphon be filled with water, and if it be immersed to such a depth that the water can rise, as above said, to the bending B, it appears evident, and incontestable, that the water in the part BH, will force down that contained in CN. But this cannot take place without the water contained in AB following it; hence the water will continually ascend from A to B, and fall down into the vessel, through the branch BC. Here then we have a perpetual motion.

Nothing is more specious; but unfortunately this illusion is destroyed also by experience; the water does not fall through the branch BC; on the contrary, it rises till the branch AB alone is full.

We think it our duty to subjoin here another idea of a perpetual motion, by means of two siphons, though the siphons employed for this purpose are not altogether capillary. It deserves the more attention, as it was not proposed by an obscure person, but by one who is justly classed among the greatest mathematicians: we mean the celebrated John Bernoulli.

Let there be two liquors, said Bernoulli, susceptible of being mixed together, the specific gravities of which are as the lines AB and CD; it is well known that if two tubes, which communicate with each other, have their heights above the branch of communication in the same ratio, the shortest branch may be filled with the heaviest fluid, and the longest with the lightest, and these two fluids will remain in equilibrio; hence it follows, that if the longer branch be cut somewhere below the length it ought to have,

the fluid contained in this branch will run into the lower one.

Let us now suppose that the shorter branch EF, pl. 4, fig. 26, is filled with a fluid composed of two liquors of different specific gravities, and that a filtre be placed in the point F, so as to afford a passage only to the lighter; let the tube FG be filled with the latter, and let its height be somewhat less, in order to establish an equilibrium between the liquor in the branch EF, and that in FG.

Things being in this state, as the filtre suffers only the lighter liquor to pass, the latter, in consequence of the equilibrium being destroyed, will be impelled outwards, through the orifice G; and consequently may be conveyed by a small pipe into the orifice E, where it will again mix with the liquor contained in EF: and this effect will always continue, because the column of liquor GF will be too light to counterbalance the compound column EF. Here then we have a perpetual motion; and this, says Bernoulli, is that which maintains the rivers, by means of the water of the sea; for, adhering to the old ideas, in regard to the origin of fountains, he imagined it was by a similar mechanism that the sea water, deprived of its salt, was conveyed to the summits of the mountains. He only rejected the idea of those who pretend that it rises above its level, in consequence of the property of capillary tubes; for he remarked that in that case it would not flow down.

We will not venture to assert what might be the case, if it were possible to realise the suppositions of Bernoulli: we are however strongly inclined to believe, that it would not succeed; and as the above reasoning, in regard to capillary tubes, though in appearance convincing, is belied by experience, we are of opinion that the case would be the same with this of Bernoulli.

PROBLEM L.

The prodigious force of moisture to raise burthens.

One of the most singular phenomena in physics, is the force with which the vapour of water, or moisture, penetrates into those bodies which are susceptible of receiving it. If a very considerable burthen be affixed to a dry and well stretched rope, and if the rope be only of such a length as to suffer the burthen to rest on the ground, on moistening the rope, you will see the burthen raised up.

The anecdote respecting the famous obelisk erected by Pope Sixtus v, before St. Peter's at Rome, is well known. The chevalier Fontana, who had undertaken to raise this monument, was, it is said, on the point of failing in his operation, just when the column was about to be placed on its pedestal. It was suspended in the open air; and as the ropes had stretched a little, so that the base of the obelisk could not reach the summit of the pedestal, a Frenchman cried out "Wet the ropes." This advice was followed; and the column, as if of itself, rose to the necessary height, to be placed upright on the pedestal prepared for it.

This story however, though often repeated, is a mere fable. Those who read the description of the manœuvres which Fontana employed to raise his obelisk, will see that he had no need of such assistance. It was much easier to cause his capstans to make a few turns more, than to go in quest of sponges and water to moisten his ropes. But the story is established, and will long be repeated in France, because it relates to a Frenchman.

However, the following is another instance of the power of moisture, in overcoming the greatest resistances: it is the method by which millstones are made. When a mass of this stone has been found sufficiently large, it is cut

into the form of a cylinder, several feet in height; and the question then is, how to cut it into horizontal pieces, to make as many millstones. For this purpose, circular and horizontal indentations are cut out quite around it, and at proper distances, according to the thickness to be given to the millstones. Wedges of willow, dried in an oven, are then driven into the indentations, by means of a mallet. When the wedges have sunk to a proper depth, they are moistened, or exposed to the humidity of the night, and next morning the different pieces are found separated from each other. Such is the process which, according to M. de Mairan, is employed in different places for constructing millstones.

By what mechanism is this effect produced? This question has been proposed by M. de Mairan; but in our opinion, the answer which he gives to it is very unsatisfactory. It appears to us to be the effect of the attraction by which the water is made to rise in the exceedingly narrow capillary tubes with which the wood is filled. Let us suppose the diameter of one of these tubes to be only the hundredth part of a line; let us suppose also, that the inclination of the sides is one second, and that the force with which the water tends to introduce itself into the tube, is the fourth part of a grain: this force so very small, will tend to separate the flexible sides of the tube, with a force of about 50000 grains; which make about 8¾ pounds. In the length of an inch let there be only 50 of these tubes, which gives 2500 in a square inch, and the result will be an effort of 21875 pounds. As the head of a wedge of the kind above mentioned, may contain four or five square inches, the force it exerts will be equal to about 90 or 100 thousand pounds; and if we suppose 10 of these wedges in the whole circumference of the cylinder, intended to form millstones, they will exercise together an effort of

900 thousand or a million of pounds. It needs, therefore, excite no surprise that they should separate those blocks into the intervals between which they are introduced.

PROBLEM LI.

Of Papin's Digester.

Papin's digester is a vessel, by means of which a degree of heat is communicated to water, superior to that which it acquires when it boils. Water indeed exposed to common air, or the mere pressure of the atmosphere, however strongly it boil, can acquire only a certain degree of heat, which never varies; but that inclosed in Papin's digester acquires such a degree, that it is capable of performing operations, for which common boiling water is absolutely insufficient. A proof of this will be seen in the description of the effects produced by this machine.

This vessel may be of any form, though the cylindric or spherical is best; but it must be made of copper or brass. A cover must be adapted to it, in such a manner, as to leave no aperture through which the water can escape. To prevent the vessel from bursting, a hole is made in the side of it, or in the cover, some lines in diameter, with an ascending tube fitted into it, on which is placed the arm of a lever kept down by a weight. This lever serves as a moderator to the heat; for if there were no weight on the aperture of this regulator, the water, when it attains to a certain degree of common ebullition, would escape almost entirely through the aperture, either in water or in steam: if the weight be light, the water, in order to raise it, must assume a greater degree of heat. If there were no regulator of this kind, the machine might burst into pieces, by the expansive force of the steam. For this reason, it is proper that the machine should be of ductile copper, and not of cast iron; because the former

of these metals does not burst like the latter, but tears as it were; so that it is not attended with the same dangerous consequences.

When the machine is thus constructed, fill it with water, and having fitted on the cover, let it be fastened strongly down by a piece of iron placed over it, which can be well secured by screws: then complete the filling it through the small tube which serves as a moderator or register, and set it over a strong fire. The water it contains cannot boil; but it acquires such a degree of heat that it is able, in a short time, to soften and decompose the hardest bodies; while the same effect could not be produced by ebullition continued for several weeks: it is even said that the heat may be carried so far, as to bring the machine to a state of ignition; in which case it is evident that the water must be in the same; but in our opinion this experiment is exceedingly dangerous.

However, the following are some of the effects of this heat, when carried only to three, four, or five times that of boiling water.

Horn, ivory, and tortoise shell, are softened in a short time, and at length reduced to a sort of jelly.

The hardest bones, such as the thigh bone of an ox, are also softened, and at length entirely decomposed; so that the gelatinous part is separated from them, and the residuum is nothing but earthy matter. When no more than the proper degree of heat has been employed in this decomposition, the jelly may be collected: it coagulates as it cools, and may be made into nourishing soup, which would be equal to that commonly used, if it had not a taste somewhat empyreumatic. This jelly may be absolutely formed into dried cakes, which will keep exceedingly well, provided they be preserved from moisture. They may serve as a substitute for meat soup, &c.

Hence it may be conceived, how useful this machine

might be rendered in the arts, for economy, and in navigation.

From these bones, thrown away as useless, food might be obtained for the poor in times of scarcity, or some ounces of bread, with soup made from the above cakes, would form wholesome and nourishing aliment.

Sailors might carry with them during their long voyages some of these cakes, preserved in jars hermetically sealed; they would cost much less than preparations of the same kind from meat, as the matter of which the former are made is of no value. The sailors, who are accustomed to live on salt provisions, would be less exposed to the scurvy. At any rate, these cakes might be reserved till a scarcity of fresh meat, or of any other kind of provisions, which so often takes place at sea. It would be a great advantage to have collected into a small volume the nourishing part of several oxen; for since a pound of meat contains, at least, an ounce of gelatinous matter reduced to dryness, it thence follows, that 1500 pounds of the same meat, which is the whole weight of a bullock, would give only 94 pounds, which might be easily contained in an earthen jar.

In the last place, it would be of great use to the arts, to be able, with a machine of this kind, to soften ivory, horn, bone, and wood, so as to render them susceptible of being moulded into any form at pleasure.

PROBLEM LII.

What is the reason that in winter, when the weather suddenly becomes mild, the air in houses continues, even for several days, to be colder than the exterior air?

This question will present no difficulty to those who are acquainted with the phenomena of the communication of heat. It is well known indeed, that the rarer a body is, the less time it requires to become hot, or to cool; and, on

the other hand, that the denser it is, the more obstinately it retains the heat it has acquired.

Hence it may be easily conceived, that when cold has prevailed for some time, all the bodies of which our houses are composed, are cooled to the same degree as the exterior air. But when the exterior air, by any particular cause, becomes suddenly warmer, these bodies do not immediately assume the same temperature: they lose only gradually that which they had acquired; and during this time the interior air, which is surrounded by them, retains the same degree of cold.

Houses strongly built, that is to say constructed of good squared stone, which have thick walls, must, for this reason, retain much longer the cold they have received from the exterior air; and, for the same reason, the air within these houses will remain longer at a temperature below that of the atmosphere, than in houses built in a slighter manner: for the same reason also, it will be less cold in such houses, at the commencement of winter, than in slighter houses.

PROBLEM LIII.

Of some natural signs, by which a change of the present temperature of the air can be predicted.

This part of philosophy, we must confess, is still in its infancy. No person has ever yet been able to make a series of observations, sufficient to show the connection which subsists between the temperature of the air, and different physical signs which are commonly supposed to precede them. We expected to find a great deal on this subject in Father Cotte's *Traité de Météorologie;* but this work, exceedingly useful in other respects, does not say a word on the subject. We shall therefore here confine ourselves to a few of those signs, which are commonly

considered as indications of good or bad weather. We will not however warrant them as infallible.

1st. When a strong hoar frost is seen on the ground in the morning, during winter, it will not fail to rain the second or third day after, at farthest.

2d. It has also been remarked, that it commonly rains on the day when the sun appears red or pale; or the next day when the sun at the time of setting is involved in a large cloud: in this case, if it rains, the next day is exceedingly windy. The same thing almost always takes place also, when the sun at setting appears pale.

3d. When the sun is red at the time of his setting, it is commonly a sign of fine weather the next day: on the other hand if he rises red, rain or a strong wind commonly takes place the day after.

4th. When a white mist or vapour is seen to rise from the water or marshy places, after the sun has set, or a little before he rises, one may conjecture, with some degree of probability, that the next day will be fine.

5th. When the moon is pale, it indicates rain; when red, wind may be expected; and when of a pure and silver colour, it is a sign of fair weather, according to this verse:

Pallida luna pluit, rubicunda flat, alba serenat.

6th. When small black clouds detached from the rest, and lower, are seen wandering here and there, or when several clouds are seen collected in the west, at sun rise, it is a sign of a future tempest. If these clouds, on the other hand, disperse, it is a sign of fine weather. When the sun appears double or treble through clouds, it prognosticates a storm of a long duration. It is the sign of a great storm also, when two or three broken and spotted circles are seen around the moon.

7th. When an iris, or rather halo, is seen around the moon, it is a sign of rain; and if a halo is seen around the

sun, during bright and serene weather, it is also a sign of rain; but if the halo appear in the time of rain, it is a sign of fine weather.

8th. If animals show signs of fear and uneasiness, while the weather is exceedingly calm and close, it is almost certain that a storm will ensue. The barometer, in this case, falls exceedingly low all of a sudden.

9th. Indications of rain not being far distant, may be gathered from the actions of various animals, as follows.

When birds are seen more employed than usual in searching among their feathers, for the small insects which torment them;

When those which are accustomed to remain on the branches of trees, retire to their nests;

When the sea-gulls, and other aquatic fowls, and particularly geese, make a greater noise than usual;

When the swallows fly very low, and seem to skim over the surface of the earth;

When pigeons return to the pigeon-house before their accustomed time;

When certain fish, such as the porpoise, sport at the surface of the water;

When the bees do not quit their hives; or fly only to a very short distance;

When sheep bound in an extraordinary manner, and push each other with their heads;

When asses shake their ears, or are very much stung by the flies;

When flies and gnats sting more severely, and are more troublesome than usual;

When a great number of worms issue from the earth;

When frogs croak more than usual;

When cats rub their heads with their fore-paws, and lick the rest of their bodies with their tongue;

When foxes and wolves howl violently;

When the ants quit their labour, and conceal themselves in the earth;

When the oxen, lying together, frequently raise their heads, and lick each other's muzzles;

When the cocks crow before their usual hour;

When domestic fowls flock together, and squeeze themselves into the dust;

When toads are heard crying in elevated places.

10th. During the time of rain, if any small blue space of the heaven be observed, one may almost be assured that the rain will not be of long duration: this sign is well known to huntsmen.

11th. Very violent storms, when accompanied with earthquakes, are almost always preceded by an extraordinary calm in the air, and of that alarming kind which seems the silence of nature about to be convulsed. Animals, more sensible of these natural indications than man, are frightened by it, and hasten to their retreats. Sometimes a hollow subterranean noise is heard. When all these signs are united, the inhabitants of the unfortunate countries, subject to these destructive scourges, ought to fly from their houses, that they may avoid the danger of being buried under their ruins.

We shall not entertain our readers with the prolix description which Ozanam, or his continuator, here gives of one of these storms which spread devastation throughout the kingdom of Naples, in the time of the famous queen Jean.

12th. An English navigator says he observed that an aurora-borealis was always followed, in the course of a few days, with a violent gale from the south-east; and he gives this notice to navigators, about to enter the channel, that they may be upon their guard *.

* See Philos. Transact. vol. LXV, p. 1.

PROBLEM LIV.

The Phial of the Elements.

Some philosophers have pretended to give an idea of the invariable and necessary arrangement of what they call the four elements, by the following process.

Take glass, or black enamel, or any other vitreous body, reduced to powder, to represent the earth.

Water will be represented by the fixed alkali of tartar per deliquium, otherwise called oil of tartar.

Air may be represented by spirit of wine, slightly tinctured blue by means of turnsole.

And fire may be represented by means of petroleum, highly rectified, to which a light red colour has been communicated by Brazil wood.

Having prepared these four matters, pour them into a long narrow glass phial, till four-fifths of it are filled; taking care to pour nearly an equal quantity of each, and close the phial hermetically. If you then shake the phial, the whole will be mixed together; but as soon as it is left at rest, the four different matters will separate from each other: the pulverised glass or enamel will fall to the bottom; the fixed alkali or oil of tartar will place itself above it; the spirit of wine will be next; and last of all the petroleum, according to the order of their specific gravities.

Remark.—It may be easily seen that the inventors of this pretended representation were very poor philosophers; for though it be true, in general, that earth is heavier than water, water than air, and the latter than fire, it is entirely false that fire occupies the upper part, as a very intense cold certainly prevails in the celestial regions. Besides, all these elements, as they are here called, are generally mixed together, since the hardest stone contains a third of water, a great number of times its volume of air, and more or less fire according to its temperature.

PROBLEM LV.

To separate two liquors, which have been mixed together.

This operation is merely an application of the property of capillary tubes, and of that law of nature by which homogeneous fluids, when near each other, unite together. This is observed to be the case with two drops of mercury, or water or oil, when they come into contact. It is even probable, that before they are in contact, they lengthen themselves, and mutually approach each other.

However, if you are desirous of separating water, for example, from the oil with which it has been mixed, take a bit of cloth or sponge, well moistened in water, and place it, immersing it by one end, in the vessel containing the liquors to be separated: the other end must be made to pass over the edge of the vessel, and to hang down much lower than the surface of the liquor: this end will soon begin to drop, and in this manner will attract and separate all the water mixed with the oil.

If it be required to draw off the oil, the rag or sponge must be first immersed in that liquid.

But those who should imagine that wine or alcohol can be separated in this manner from water, would be deceived: in order that the operation may succeed, the two liquors must be nearly immiscible together, otherwise they will both pass over at the same time. This process, therefore, cannot be employed for separating water from wine, though it has been given in the preceding editions of the Mathematical and Philosophical Recreations, with many others equally childish.

The colouring part of the wine appears indeed to remain behind, because it is less attenuated than the phlegm and spirit; but in reality these two liquors, of which wine essentially consists, are not separated from each other.

?ROBLEM LVI.

. · :e cause *of the Ebullition of Water?*

.' ıis question, on the first view, may appear as ·uportance, it deserves to be examined; for those ıight imagine that the bubbling observed in water ‹ ı boils, is the necessary consequence of the heat it re·ᴄs, would be deceived. That the contrary is the case .·y be proved by the following experiment.

Immerse, with the necessary care, any vessel, such as a .ottle filled with water, for example, into a kettle contain-.ıg water in a strong state of ebullition; the water in the bottle will not fail to assume, in a short time, a degree of heat absolutely equal to that of the water which boils; this will be proved by means of a thermometer, yet the smallest sign of ebullition will not be observed in it.

What then is the cause of that observed in the water, which is immediately exposed to the action of the fire?

In our opinion, the boiling up is the effect of portions of the water, which touch the sides of the vessel, suddenly converted into vapour by coming into contact with these sides; for when a vessel rests on burning coals, its bottom tends to receive a degree of heat much greater than that necessary to convert immediately into vapour a drop that falls upon it. The pellicle of water which touches the bottom must, therefore, be continually converted into vapour; and this indeed is the case; for bubbles of an elastic fluid are continually seen rising from the bottom, and these bubbles, carried by an accelerated motion to the surface, in consequence of their lightness, produce there that bubbling which constitutes ebullition.

But the water contained in the bottle, immersed in the boiling liquid, cannot assume a degree of heat greater than that of boiling water; because, however strong the ebullition may be, the water does not acquire a greater degree

of heat. On the other hand, a piece of metal, heated only to the degree of boiling water, does not convert the water which it touches into vapour; the water therefore contained in the interior vessel, though become equally warm, cannot boil. Such is the explanation of the two phenomena; and their necessary connection with each other, as well as with the assigned cause, proves the truth of that cause.

PROBLEM LVII.

What is the reason that the bottom of a vessel, which contains water in a high state of ebullition, is scarcely warm?

Before we attempted to enquire into the cause of this phenomenon, we thought it proper first to assure ourselves of the fact, for fear of exposing ourselves to ridicule, like those who explain in so ingenious a manner the phenomenon of the child in Silesia with the golden tooth; a phenomenon however which was only a deception, as well as that which occurred to the marquis of Vardes, explained with so much sagacity by Regis, and which however was the trick of a servant. And the case is the same with many others, which ought first to be confirmed, before we attempt to explain them. We brought water therefore to a strong state of ebullition, in an iron vessel, and having touched the bottom of it, while the water was boiling, we indeed found that it had but a very moderate heat; it did not begin to be burning hot, till the moment when the ebullition had almost ceased.

In our opinion, this effect is produced in the following manner: we have already shown, that the ebullition is occasioned by the pellicle of water, which touches the bottom of the vessel, being continually converted into vapour. This conversion into vapour cannot take place, without the bottom always losing some of that heat, which it acquires by the contact of the coals or fire. But during the interval

between the moment when the vessel is taken from the fire, and that when it is touched, as no new igneous fluid reaches it, though it still continues to boil, it is probable that the remainder of this fluid is absorbed by the water which touches the bottom, and which is converted into vapour.

Without giving this explanation as absolutely demonstrative, we are strongly inclined to think that such is the real case; and what seems to give it more probability is, that while the bottom of the vessel, from which the boiling proceeds, is but little hot, the sides have the heat of boiling water; so that the finger would be burnt, were it kept as long on them as it can be kept on the bottom. But no sooner has the boiling ceased, than the bottom itself receives part of the heat of the water, and the finger cannot then touch it, without being burnt.

REMARK.—The solution of the following little problem depends, in all probability, on a similar cause.

To melt lead in a piece of paper.

Wrap up a very smooth ball of lead in a piece of paper, taking care that there be no wrinkles in it, and that it be every where in contact with the ball; if it be held, in this state, over the flame of a taper, the lead will be melted without the paper being burnt. The lead, indeed, when once fused, will not fail in a short time to pierce the paper, and to run through.

PROBLEM LVIII.

To measure the moisture and dryness of the air. Account of the principal hygrometers invented for that purpose; their faults, and how to construct a comparative hygrometer.

The air is not only susceptible of acquiring more or less heat, but also of becoming more or less humid. It belongs

therefore to philosophy, to measure this degree of moisture; especially as this quality of the air has a great influence on the human body, on vegetation, and many other effects of nature.

This gave rise to the invention of the hygrometer, an instrument proper for measuring the humidity of the air.

But it must be allowed, that the instruments hitherto invented for this purpose do not give that result which might have been expected. We have hygrometers indeed, which indicate that the air has acquired more or less moisture than it had before; but they are not comparative, that is to say, they do not enable us to compare the moisture of one day or place with that of another*. It is, however, proper that we should make known the different kinds of hygrometers, were it only that we may be able to appreciate their utility.

I. As fir-wood is highly susceptible of participating in the dryness or humidity of the air, an idea has been conceived of applying this property to the construction of an hygrometer. For this purpose, a very thin small fir board is placed across between two vertical immoveable pillars, so that the fibres stand in a horizontal direction; for it is in the lateral direction, or that across its fibres, that fir and other kinds of wood are distended by moisture. The upper edge of the board ought to be furnished with a small rack, fitted into a pinion, connected with a wheel, and the latter with another wheel having on its axis an index. It may be easily perceived, that the least motion communicated by the upper edge of the board to the rack, by its rising or falling, will be indicated in a very sensible manner by the index; consequently, if the motion of the index

* This is not altogether correct. M. de Luc has described, in the *Philosophical Transactions*, the method of constructing a hygrometer, which approaches very near to what might be desired in this respect. We have added it to this article.

be regulated in such a manner, that from extreme dryness to extreme moisture it may make a complete revolution, the divisions of this circle will indicate how much the present state of the atmosphere is distant from either of these extremes.

This invention is ingenious; but it is not sufficient. The wood retains its moisture a long time after the air has lost that with which it is charged; besides, the board gradually becomes less sensible to the impressions of the air, and therefore produces little or no effect.

II. An hygrometer may be made also with the beard of a wild oat, fixed on a small column, placed in the centre of a round box: the other extremity of the beard passes through the centre of the cover of the box, the circumference of which is divided into equal parts; in the last place a small index, made of paper, is adapted to the extremity of the beard. In order to afford access to the air, it is necessary that the sides of the box should be open, or cut into holes.

When this instrument is exposed to dryer or moister air, the small index, by turning round, either in the one direction or the other, indicates the state of the atmosphere.

But this hygrometer, which is exceedingly sensible at first, gradually loses this property: consequently, it is a very imperfect instrument, as well as the following.

III. Suspend a small circular plate by a fine string, or piece of catgut, fastened to its centre of gravity; and let the other end of the string be attached to a hook. According as the air is more or less moist, you will see the small plate turn round, in one direction or in another. This small machine may be covered by a bell-glass, to prevent its being deranged by the agitation of the air; but the bell must be elevated above the base on which it is placed, that the air may have access to the string.

The hygrometers commonly sold are constructed on this principle. They consist of a kind of box, the fore part of which represents an edifice with two doors. On one side of the metal plate which turns round, stands the figure of a man with an umbrella, to defend him from the rain; and on the other, a woman with a fan. The appearance of the former of these figures, indicates damp, and that of the other, dry weather. This pretended hygrometer can serve for no other purpose, than to amuse children; the philosopher must observe, that, as the variations of humidity are transmitted to this instrument only by degrees, it will indicate moisture or drought, when the state of the atmosphere is quite contrary.

If a piece of cat-gut, made fast at one extremity, be conveyed over different pullies, as A, B, C, D, E, F, G, &c, pl. 4 fig. 27, so as to make several turns, backwards and forwards; and if a weight P, be suspended from the other extremity, it may be easily seen, that it must rise or fall in a more sensible manner, in consequence of the moisture or dryness of the air, according as the number of the turns backwards and forwards is greater. But this will be indicated better if an index HK, turning on a pivot I, and placed in such a manner, that the part IK shall be much longer than IH, be made fast to the extremity of the cord H: the slightest change in the moisture of the air, will be manifested by the point K of the index.

V. An hygrometer may be constructed also in the following manner. Extend a cord, five or six feet in length, between the pegs A and B, pl. 4 fig. 28, and suspend from the middle of it C, a weight P, by a thread PC. If an index DF, turning on the pivot E, and having the part EF much longer than DE, be adapted to the thread PC, as seen at D; as the cord ACB will be shortened by moisture and lengthened by drought, the weight P, as well as the point D, will rise or fall, and consequently make the index pass over a

certain portion of the arc GH, the divisions on which will indicate the degree of moisture or dryness.

VI. Put into the scale of a balance any salt that attracts the moisture of the air, and into the other a weight, in exact equilibrium with it. During damp weather, the scale containing the salt will sink down, and thereby indicate that the state of the atmosphere is moist. An index, to point out the different degrees of drought or moisture, may be easily adapted to it.

This instrument, however, is worse than any of the rest; for salt, immersed in moist air, becomes charged with a great deal of humidity; but loses it very slowly when the air becomes dry: fixed alkali of tartar even imbibes moisture, till it falls in deliquium; that is to say, till it is reduced to a liquid or fluid state.

VII. Music also may be employed to indicate the dryness or moisture of the air. The sound of a flute is higher during dry than during moist weather. If a piece of catgut then, extended between two bridges, be put in a state of vibration, it will emit a tone with which a tonometre must be brought into unison. When the weather becomes moister, the string will emit a lower sound; and the contrary will be the case when the air becomes drier.

VIII. M. de Luc of Geneva, to whom we are indebted for an excellent work on thermometers and barometers, attempted to construct a comparative hygrometer, and published a paper on that subject in the Philosophical Transactions. The description of this hygrometer is as follows.

It has a great resemblance to a thermometer. The first and principal part is a cylindric reservoir of ivory, about $2\frac{1}{2}$ inches in length, the cylindric cavity of which is $2\frac{1}{2}$ lines in diameter, and the thickness $\frac{1}{4}$ or $\frac{3}{16}$ of a line. This piece of ivory must be cut from about the middle of an elephant's tooth, both in regard to its thickness and length; and it is necessary that the cavity should be pierced in a

direction parallel to that of the fibres. A representation of this piece is seen fig. 29, n°. 1, pl. 5, where it is denoted by the letters ABC.

The second piece is a tube of turned copper, one end of which fits exactly into the ivory cylinder, while the other receives into its cylindric cavity a glass tube of about a quarter of a line internal diameter. A representation of it is seen fig. 29, n°. 2.

These three pieces are strongly fixed to each other, by introducing into the ivory cylinder the end of the copper tube, destined to fill it, having first put a little fish glue between them. To unite these parts better together, the neck of the ivory cylinder ought to be surrounded by a virol of copper.

A glass tube of about 30 inches in length, and of such a size as to fit into the same cavity, is also introduced into it, as seen fig. 29, n°. 3, which represents the instrument completely constructed.

It is then filled with mercury, in such a manner that it shall rise to about the middle of the glass tube, and the ivory reservoir is immersed in water ready to freeze, taking care to maintain it at that temperature for several hours; for the ivory will require ten or twelve before it absorbs all the moisture it is capable of receiving. As soon as this reservoir is immersed in the water, the mercury is seen to rise, at first very quick, and then more slowly, until it at length remains stationary towards the bottom of the tube. This place, which ought to be some inches above the insertion of the glass tube into the copper one, must be marked 0, which signifies the zero of dryness, or the greatest humidity. This point, as we have said, must be some inches higher than the copper tube: for it has been remarked, that if the instrument be immersed in hot water, the mercury falls still lower, and this

interval below zero is left for the purpose of marking these divisions.

We must here acknowledge, that we do not properly understand how M. de Luc proceeds in order to render his instrument comparative; something, in our opinion, still remains to be done to give it that property. We must therefore refer the reader to the original memoir, in the *Journal de Physique* of the abbé Rozier, for the year 1775. It will be sufficient to observe, that this hygrometer is very sensible; scarcely has it been placed in air more or less humid, than it gives indications of that sensibility, by the rise or fall of the mercury; but it requires, and always will require, to be accompanied with a thermometer; for the same degree of humidity has a greater effect on it during warm weather, than during cold: besides, the mercury rises or falls independently of moisture, merely by the effect of heat. This instrument, therefore, requires a double correction; the first to keep an account of the dilatation which the mercury experiences by heat, a correction which will be minus whenever the heat exceeds the term of freezing; the second, to reduce the effect of the moisture observed, to what it would have been had the temperature been at freezing.

It may be readily conceived, of how great advantage it would be, in regard to the improvement of this hygrometer, to find a degree of dryness, or of less humidity, fixed and determinable in every country, to serve as a second fixed term, like that of water reduced to the temperature of melting ice, namely that of the greatest humidity: this would tend greatly to simplify the graduation of the instrument, which, according to the method of M. de Luc, appears to us to be complex, and uncertain. But this is enough on the present subject, respecting which the nature of our work will not permit us to enter into farther details.

PROBLEM LIX.

On the supposition of what we have before shown, in regard to the tenuity of the particles of light, and their great velocity; what loss of its substance may the sun sustain, in a determinate number of years?

One of the most specious objections made to the Newtonian theory of light, is, that if light consisted of a continual emanation of particles, thrown off from luminous bodies, the sun would have sustained such a loss of his substance, that he must have been extinguished or annihilated, since the time at which he is commonly supposed to have been created. This objection we have always considered as of little weight; and we have long been convinced that, assuming as basis what can be easily proved in regard to the tenuity of the particles of light, and their great velocity, a very probable hypothesis could be formed, from which it might be shown, that no sensible diminution could have taken place in the sun, during the course of the 6000 years, which he is commonly supposed to have existed.

We have since seen, in the Philosophical Transactions, a similar calculation by Dr. Horsley, to show the frivolity of such an objection. But as there are different methods of considering the same question, our reasoning on the subject is as follows: it has nothing in common with that of the learned Englishman, but the prodigious tenuity of the particles of light.

To form this calculation, we suppose and require it may be granted, that at each instantaneous emanation of light from the sun, this luminary projects in every possible direction all the particles of light at its surface.

We require it may be granted also, that this emanation is not absolutely continued, but composed of a multitude of instantaneous emanations or jets, which succeed each

other with prodigious rapidity: we shall suppose that there are 10,000 in a second. As the retina of the eye preserves for about $\frac{1}{7}$ of a second the impression it receives, it is evident that the impression made by the sun will be absolutely continued in regard to us.

We shall suppose also, what is almost proved, that the diameter of a particle of light is scarcely the 1000000000000th part of an inch.

According to these suppositions, it is evident that the sun, at each emanation, deprives himself of a luminous pellicle, the thickness of which is as before stated; consequently, in the course of a second, it will be the 100000000th part of an inch, and in 100000000 seconds this luminary therefore will have lost an inch in thickness. But 100000000 seconds are nearly three years: in three years, then, the sun will have lost only an inch in thickness.

Hence it appears, that in the course of 3000 years, this loss will amount to 1000 inches, or $83\frac{1}{3}$ feet in depth; and during the 6000 years, which we suppose the sun to have existed, it will be $166\frac{2}{3}$. Hence it follows, that before the sun can lose one second only of his apparent diameter, forty millions of years must elapse; for the diminution of a second in the apparent diameter of the sun corresponds to 360000 yards: if in the course of 6000 years, the diminution is only about 54 yards in depth, it will be found, by the rule of proportion, that it will require 40 millions of years to make it extend to the depth of 360000 yards in thickness, or one second of apparent diameter.

We need therefore entertain no fear of the sun becoming extinct. Our children and grand-children, at least, are secured from being witnesses of that fatal event.

We shall here add, that we have not taken the benefit of all the advantages we might have employed; for we might have extended this period much farther; and Dr.

Horsley indeed finds a much greater interval between the present moment and the final consumption of the sun. But we have confined ourselves to those suppositions which are most admissible.

PROBLEM LX.

To produce, amidst the greatest heat, a considerable degree of cold, and even to freeze water. On artificial congelations, &c.

It is a very singular phenomenon, and highly worthy of admiration, that a cold far exceeding that of winter can be produced even in the middle of summer; and what adds to the singularity is, that this production of cold does not take place unless the ingredients employed become liquid. Sometimes even by re-acting on each other they produce a strong effervescence. We shall first take a cursory view of the different means of producing cold; and then endeavour to give some explanation of the phenomenon.

I. Take water cooled only to the temperature of our wells, that is to say, to 10 degrees of Reaumur's thermometer, and for every pint throw into it about 12 ounces of pulverised sal ammoniac; this water will immediately acquire a considerable degree of cold, and even equal to that of congelation. If a smaller vessel then containing water be put into the one containing this mixture, the water in the former will freeze, either entirely or in part. If it freezes only in part, make a mixture in another vessel, similar to the first, and immerse in it the half-frozen water: by these means it will be entirely congealed.

If you employ this water half frozen, or at least greatly cooled in the interior vessel, and throw into it sal ammoniac, the cold produced will be much more considerable: a cold indeed several degrees below that of ice will speedily be the result.

If this mixture be made in a flat vessel on a table, with

a little water placed between them, the ice formed below will make the vessel adhere to the table.

The solution of the salt must be accelerated as much as possible, by stirring the mixture with a stick; for the speedier the solution, the greater will be the cold.

II. Pulverise ice, and for one part of it mix two parts of marine salt; stir well the mixture, and a cold equal to that of the severest winter will be produced in the middle of the mass. By these means Reaumur was able to produce a cold 13 degrees below congelation.

Saltpetre, employed in the same quantity, will produce a cold only 3 or 4 degrees below freezing. It is a mistake therefore, as Reaumur observes, to imagine that saltpetre produces a greater effect than marine salt. Saltpetre is employed only because it is cheaper; and besides, when artificial cold is applied to domestic purposes, it is not necessary that it should be considerable.

Instead of saltpetre, Alicant soda, or the ashes of green wood, which contain an equivalent salt, might be employed: the same effect would be obtained, and at a much less expence.

III. A cold much greater, however, than any of the preceding, may be produced in the following manner. Take snow and well concentrated spirit of nitre, both cooled to the degree of ice; pour the spirit of nitre on the snow, and a cold 17 degrees below that of congelation will be immediately excited.

If you are desirous of producing a cold still more considerable, surround the snow and spirit of nitre with ice and marine salt; which will produce a cold 12 or 13 degrees below zero; if you then employ the snow and spirit of nitre cooled in this manner, a cold equal to 24 degrees below zero will be the result. This cold is much greater than that produced by Fahrenheit; for it did not exceed 8 degrees of his thermometer below zero, which amount to 17½ degrees of Reaumur, below the same term.

But this is nothing in comparison of what the philosophers of Petersburg performed, towards the end of the year 1759. Assisted by a cold of 30 degrees and more, they cooled snow and spirit of nitre below that temperature, and by these means obtained a degree of cold which, reduced to the scale of Reaumur's thermometer, was more than 170* degrees below zero. It is well known that at this term mercury freezes, and of the consequences of this experiment we have spoken elsewhere.

IV. There is still another method of producing a cold superior to that even which is necessary to freeze water. It is founded on a very singular property of evaporable fluids. Immerse the bulb of a thermometer in one of these fluids, such as well dephlegmated spirit of wine, and then swing it backwards and forwards in the air, to excite a current like that of the wind, which promotes the evaporation of the fluid; you will soon see the thermometer fall: by employing ether, the most evaporable of all liquors, you may even make the thermometer fall to 8 or 10 degrees below zero.

Very curious things might be said in regard to this property of evaporation; but to enlarge farther on the subject would lead us too far. We shall therefore only observe, that this method of cooling liquors is not unknown in the east. Travellers, who are desirous of drinking cool liquor, put their water into jars made of porous earthen ware, which suffers the moisture to ooze through it. These vessels are suspended on the sides of a camel, in such a manner as to be in continual motion, which answers the same purpose as if they were exposed to a gentle wind, and which causes the moisture to evaporate. By these

* This number, when corrected, ought to be only 31½ below water-freezing on Reaumur; or 39, that is 71 below water-freezing, on Fahrenheit. See the remark at the end of Problem 18.

means the remaining liquor is so much cooled, as to approach the degree of congelation.

We shall now offer a few observations on the cause of these singular effects, beginning with the means explained in the first three articles.

When ice and marine salt, or spirit of nitre and snow very much cooled, are mixed together, it is observed that cold is not produced unless these substances be dissolved. From this circumstance there is reason to conjecture, that the mixture absorbs the igneous fluid diffused throughout the surrounding bodies, or those surrounded by the mixture, which amounts to the same thing. The melting mixture produces, in this case, the same effect as a dry sponge applied to a moist body: as long as it is merely confined around it, no change will take place in it; but as soon as the sponge is at liberty to extend itself to its full volume, it will absorb a considerable part of the moisture contained in that body. It must be confessed, that we do not see the mechanism by which the frigorific mixture produces the same effect; but we may consider the above comparison as capable of giving some idea of it.

In regard to the reason why an evaporable liquor cools the bodies from which it evaporates, it appears that the most probable reason is the affinity which that liquor has to fire; so that each of its moleculæ, in flying off, carries with it some of those of the fire contained in that body. But how comes it that these moleculæ of the evaporable liquor do not combine rather with the fire which the air can furnish to it, and with which that element seems to have less adhesion than to solid bodies, since it cools more readily? This question we cannot answer; but we give the above explanation merely as a conjecture, which we have not had leisure fully to examine.

Remark.—In addition to what has been given on this

subject by Montucla, we shall here observe, that the best experiments yet made known on frigorific mixtures, without the aid of snow, are those of Mr. Walker, of Oxford: some of these are as follows:

Take strong fuming nitrous acid, diluted with water (rain or distilled water is best), in the proportion of 2 parts in weight of the former to one of the latter, well mixed and cooled to the temperature of the air, 3 parts; of Glauber's salts 4 parts; of nitrous ammonia 3½ parts*, each by weight, and reduced separately to fine powder. The Glauber's salt is to be first added to the diluted acid; the mixture must then be well stirred, and the powdered nitrous ammonia is immediately to be introduced, stirring the mixture again. The salts should be procured as dry and transparent as possible, and are to be used newly powdered.

These are the best proportions, when the common temperature is 50°. According as the temperature, at setting out, is higher or lower, the quantity of diluted acid must be proportionably diminished or increased. This mixture is little inferior to one made by dissolving snow in nitrous acid; for it sunk the thermometer from 32° to 20°; that is in all 52°. In this experiment 4 parts diluted acid were used.

Crystallized nitrous ammonia, reduced to very fine powder, sunk the thermometer, during its solution in rain water, from 56° to 8°; when evaporated gently to dryness, and finely powdered, it sunk the thermometer to 49°. Mr. Walker has frequently produced ice by a solution in water of this salt alone, when the thermometer stood at 70°. If an equal weight of mineral alkali, finely powdered, be added to the mixture, the temperature will be lowered 10 or 11° more.

* A powder composed of sal ammoniac 5 parts, and nitre 4 parts, mixed together, may be substituted for the nitrous ammonia.

As it is evident that artificial frigorific mixtures may be applied to domestic purposes, in hot climates, especially where the inhabitants can scarcely distinguish summer from winter, by the sense of feeling, it may not be amiss to give a few hints respecting the easiest method of using them.

In most cases, the following cheap one may be sufficient: Take any quantity of strong vitriolic acid, diluted with an equal weight of water, and cooled to the temperature of the air, and add to it an equal weight of Glauber's salt, in powder. This is the proportion when the temperature, set out with, is 50°; and will sink the thermometer to 5°; if the temperature be higher than 50°, the quantity of salt must be proportionally increased.

The obvious and best method of ascertaining the quantity of any salt, necessary to produce the greatest effect by solution, in any liquid, at any given temperature, is to add the salt gradually, till the thermometer ceases to sink, stirring the mixture all the time. If a more intense cold be required, double aqua-fortis, as it is called, may be used. Glauber's salt, in powder, added, will produce very nearly as much cold as when added to diluted nitrous acid. A somewhat greater quantity of the salt is required. At the temperature of 50°, about 3 parts of the salt, to 2 of the acid, will sink the thermometer from that temperature to nearly 0°; and the consequence of more salt being added is, that it retains the cold rather longer. This mixture has one great advantage in its favour: it saves time and trouble. A little water in a phial immersed in a tea-cup full of this mixture will be soon frozen, even in summer; and if the salt be added in crystals, not pounded, to double aqua-fortis, though in a warm temperature, the cold produced will be sufficient to freeze water or cream; but if diluted with one fifth of its weight of water, and cooled, it will be nearly equal to the diluted nitrous acid.

before mentioned, and will require the same proportion of the salt.

A mixture of Glauber's salt and diluted nitrous acid, sunk the thermometer from 70°, the temperature of the air and ingredients to 10°.

The cold in any of these mixtures may be kept up a long time, by occasionally adding the ingredients in the proportions indicated.

Take equal parts of sal ammoniac and nitre, in powder; and cool them, by immersing the vessel which contains them in pump water newly drawn, its temperature being generally 50°. On three ounces of this powder pour four ounces, wine measure, of pump water, at the above temperature, and stir the mixture; its temperature will be reduced to 14°, and consequently it will soon freeze the contents of any small vessel immersed in it. The cold may be continually kept up and regulated, for any period of time, by occasionally pouring off the clear saturated liquor, and adding more water; taking care to supply it constantly with as much of the powder as it can dissolve. This is a convenient mixture; for if the solution be afterwards evaporated to dryness in an earthen vessel, and reduced to powder, it will answer the purpose as well as at first; as its power does not seem to be lessened by being repeatedly treated in this manner.

All the ingredients employed by Mr. Walker being taken at the temperature of 50°, the following table will exhibit the result of a great many experiments:

		Temperature.
*	Sal ammoniac 5, nitre 5, water 16 parts .	10°
'	Do. ——— 5, do. 5, Glauber's salt 8, water 16	4
*	Nitrous ammoniac 1, water 1 . . .	4
	Do. ——— 1, soda 1, water 1 . .	7
†	Glauber's salt 3, dilute nit. acid 2	3

	Temperature.
Do. Glauber's salt 6, sal ammon. 4, nitre 2, dilute nit. acid 4	10
Do. ——— 6, nitrous ammonia 5, dilute nit. acid 4	14
Phosphorated soda 9, dilute nit. acid 4 . .	12
Do. ——— 9, nitrous ammon. 6, dilute nit. acid 4	21
†. Glauber's salt 8, marine acid 5 . . .	0
† Do. ——— 5, dilute vitriolic acid 4 . . .	3

The salts marked thus (*) may be recovered by evaporating the mixture, and may be used again repeatedly; those marked thus (†) may be recovered for use by distillation and crystallization: the dilute nitric acid was red fuming nitrous acid 2 parts, rain water 1 part: the dilute vit. acid was strong vitriolic acid and rain water, equal parts.

By a judicious management frigorific mixtures, with the aid of snow or pounded ice, mercury even may be frozen into a solid mass. Mr. Walker immersed a half pint glass tumbler containing equal parts of vitriolic acid, the specific gravity of which was 1·5596, and strong fuming nitrous acid, in mixtures of nitrous acid and snow, until the mixed acids in the tumbler were reduced to —30°; he then gradually added snow, which had been also previously cooled in a frigorific mixture to —15°, to the mixture in the tumbler, stirring the whole, and found, after some minutes, that the mercury in a thermometer immersed in the fluid had become congealed or frozen.

Quicksilver may be congealed by adding newly fallen snow to strong fuming nitrous acid, previously cooled to between —25° and —30°, which may be easily and speedily effected by immersing the vessel containing the acid in a mixture of snow and nitrous acid.

But the most powerful frigorific mixture yet discovered,

is produced by equal parts of muriate of lime and snow. An account of a very remarkable experiment of this kind is given in *Tilloch's Philosophical Magazine*, Vol. III. It was performed by Messrs. Pepys and Allen. Into a mixture of equal parts of muriate of lime at 33°, and snow at 32°, a bladder containing no less than 56 pounds of mercury was immersed, after the mixture had liquified by stirring, and when its temperature was found to be —42°; as soon as the cold mixture had deprived the mercury of so much of its heat that its own temperature was raised from —42° to + 5°, the mercury was taken from it, and put into another fresh mixture, the same in every respect as the first.

In the mean time, the muriate of lime was kept cooling, by immersing the vessel which contained it into a mixture of the same ingredients: 5 pounds of the muriate were, by these means, reduced to —15°; a mixture being made of this muriate and snow, at the temperature of 32°, in the course of three minutes, it gave a temperature of —62° or 94° below the freezing point of water.

The mercury reduced to —30° by immersion in the second mixture, and suspended in a net, was put into the new made mixture, and the whole was covered with a cloth to impede the passage of heat from the surrounding atmosphere. After an hour and 40 minutes, the 56 pounds of mercury were found solid and fixed. The temperature of the mixture, at this time, was —46°; that is 16° higher than when the mercury was put into it.

Several of those who were present at this experiment having, without attending to the consequences, taken pieces of the frozen mercury into their hands, experienced a painful sensation, which they could compare to nothing but that produced by a *burn* or a *scald*, or by a wound inflicted with a rough edged instrument. The parts of the hand which were in contact with the metal lost all sensation, and became white, and to appearance dead; a

phenomenon which alarmed the sufferers not a little: however, soon throwing away the pieces from them, as they would have done hot coals, the injury scarcely penetrated the skin; and in a little time the parts, by friction, resumed their usual sensation and colour.

Lately, on the principle of evaporation, before explained in this problem, Mr. Leslie and Dr. Marcet have frozen water, and even mercury, by inclosing them in the receiver of an air pump, and exhausting it, to produce a rapid evaporation from the surface of the containing vessel, moistened with water, or with ether.

PROBLEM LXI.

To cause water to freeze, by only shaking the vessel which contains it.

During very cold weather, put water into a close vessel, and deposit it in a place where it will experience no commotion: in this manner it will often acquire a degree of cold, superior to that of ice, but without freezing. If the vessel however be agitated ever so little, or if you give it a slight blow, the water will immediately freeze with singular rapidity. This will be the case, in particular, when the water is in vacuo.

This phenomenon is exceedingly curious; but in our opinion, it is susceptible of an explanation which must appear highly probable to those acquainted with the phenomena of congelation. Water does not congeal unless its moleculæ assume a new arrangement among themselves. When water cools, at perfect rest, its moleculæ approach each other, and the fluid which keeps it in fusion gradually escapes; but something more is necessary to determine the moleculæ to arrange themselves in a different manner, under angles of 60 or 120 degrees. This determination they receive by the shock given to the vessel: they were in equilibrio; the shock destroys that

equilibrium, and they fall one upon another, forming themselves into groupes, in such a manner as their approach to each other requires.

Another phenomenon of congelation is as follows. If you boil water, and then expose it to the frost, close to an equal quantity of unboiled water, the former will freeze sooner than the latter.

This is a fact proved by experiments, made at Edinburgh, by Dr. Black; and, in our opinion, may be easily explained; as congelation is occasioned by the moleculæ of the water approaching each other: it must congeal the sooner, if these moleculæ, before being exposed to the frost, are already closer. But water which has boiled possesses, in this respect, an advantage over that which has not boiled; for the effect of boiling is to deprive it of a great deal of its combined air: these moleculæ then, *cæteris paribus*, must arrive sooner at the term of proximity, at which they adhere to each other, and form a solid body. We are convinced, that for the same reason, water impregnated by artificial means with air, would be longer in freezing than common water.

PROBLEM LXII.

Of the figure observed sometimes in snow: Explanation of that phenomenon.

It often happens, and it has long been remarked with admiration, that the small flakes of snow have a regular figure. Such is the case, in particular, when the snow falls gently, and in very small flakes. This figure is hexagonal or stellated: sometimes it is a plain star with six radii; at other times the star is more complex, and resembles a cross of Malta, having six salient and six reentering angles. It sometimes happens that each branch presents ramifications, like the barbs of a feather; but it would be too tedious to describe them all. We shall

therefore confine ourselves to a representation of the most remarkable, as seen pl. 5 fig. 30 n°. 1, 2, 3, 4.

This phenomenon has always occasioned great embarrassment to philosophers, since the time of Descartes and Kepler, who seem to have been the first who remarked it. Bartholin wrote a dissertation *De Figura nivis hexangula*, in which he reasons very badly on the subject. It was indeed difficult to reason justly on it*, until M. de Mairan observed, as he did with great sagacity, the phenomena of congelation, and until chemistry had discovered those of the crystallization of bodies, when they pass from a fluid to a solid state.

Chemistry indeed has taught us that all bodies, the elements of which, floating in a fluid, calmly approach each other, assume regular and characteristic figures. Thus sulphur, when it becomes fixed, forms long needles: regulus of antimony has on its surface the figure of a star. Salts, when they crystallize slowly, assume regular figures also. Marine salt forms cubes, alum octaedra, gypsum a kind of wedges, regularly irregular, the laminæ of which break into triangles of determinate angles; calcareous spar, called *Icelandic Crystal*, forms oblique parallelopipeda under invariable angles; &c.

On the other hand, M. de Mairan, while observing the progress of congelation, saw that the small needles of ice, which are formed, are implanted one into the other, at regular and determinate angles, which are always 60 or 120 degrees.

Whoever is acquainted with these phenomena, will see nothing in ice and snow but a crystallization of water, condensed in cold air: one particle of frozen water meets another, and unites with it, at an angle of 60 degrees; a

* We find however that Gassendi referred the regular figure of snow to crystallization. See ad Diog. Laert. Not. opp. vol. r. p 577.

third is added, and is determined by the action of the point of the first angle, to unite itself in the same manner, &c. This is the simplest of the stars of snow, and is represented by n°. 1.

If new needles of ice are added, which will for the most part be the case, they must place themselves on the first radii, either by making an obtuse or an acute angle towards the centre. In the first case, the result will be a star, the radii of which have a kind of barbs like a feather, as in n°. 2, or like a star, as n°. 3. The last arrangement however is rare, and that of n°. 2 is more common. Some are also seen, though in less number, much more complex; but whatever may be their composition, their elements are always angles of 60 or 120 degrees.

M. Lulolf of Berlin conjectured, that these figures were occasioned by the sal ammoniac, or rather volatile alkali, with which snow is impregnated: and, in support of this idea, he mentions a very pretty experiment. Having exposed some water to freeze near the common sewer, he found the surface of it entirely covered with small stars of ice, while the frozen water, which was at a greater distance, exhibited nothing of the kind. He acknowledges however, that he was never able, by any process, to detect this principle in snow water, or snow melted in close vessels. No philosopher at present will indeed believe, that either sal ammoniac or volatile alkali exists in snow, unless accidentally; and there is no necessity of supposing it, in order to explain its crystallization in stars.

PROBLEM LXIII.

To construct a fountain, which shall alternately flow and intermit.

We have already described the mechanism of a fountain which produces this effect, and which is well known to

those acquainted with hydraulics; but as it cannot be adapted to the purposes we have here in view, we shall give another method of solving the problem.

Let ABCD, pl. 5, fig. 31, be a vessel of any form, which receives by the pipe E a continual influx of water, capable of filling it to the height GH, in the interval, for example, of two hours. Let FGI be a syphon, the upper orifice of which, immersed in the liquor, is F; let FG be the shorter, and GI the longer branch, the orifice of which I, must be considerably below the level of F; lastly, let the bore of this syphon be such, that it can draw off the liquor contained in the part GI, in the course of half an hour. These suppositions being made; if the vessel be empty, and if the water be suffered to run in by the pipe E, it will fill the vessel to the height G, in two hours, for example; but when it reaches the bending G, the syphon FGI will be filled, and the water flowing into it, in the course of somewhat more than half an hour*, it will empty, not only the water collected as far as GH, but that also which the pipe E may have furnished during that time; because this discharging pipe FGH will exhaust much more rapidly, than that which furnishes, viz, DE. The surface of the water, always descending, will at length fall to the level of the orifice F, and the air introducing itself, the play of the syphon will be interrupted: the water will then begin to rise again to the bending of the syphon at G, so that the play of the syphon will recommence, and this will be the case as long as the pipe E can furnish water.

REMARK.—It is necessary to observe, that the syphon will not perform its effect, unless it be a capillary tube as far as the bending; for if its diameter, at this place, be 5

* This time will be exactly 40 minutes; for it is the sum of a subquadruple progression, the first term of which is 30 minutes, the second 7½, &c.

or 6 lines, the water, when it reaches to a little above the bending, will flow off without filling the whole pipe, as seen fig. 31, n°. 2, and the pipe would run off a quantity of water equal only to that furnished by the pipe E. This observation was made, and with great justice, by the Abbé Para du Phanjas, who had recourse therefore, in this case, to several capillary tubes, uniting in one.

Another remedy consists in making the calibre of the discharging pipe capillary, throughout its whole length, and proportionally wide in a horizontal direction, in order that it may have the same surface, and that the same quantity of water may flow through it. By these means the discharging pipe, though single, will perform its office.

It is proper also that the orifice F, of the branch GF, should be cut as seen n°. 3, in order to facilitate the introduction of air into the syphon, when the surface of the water shall have fallen to F. This however we do not think essential.

PROBLEM LXIV.

To construct a fountain which shall flow and stop a certain number of times successively; and which shall then stop, for a longer or shorter period, and afterwards resume its intermitting course; and so on.

The solution of this problem depends on a very ingenious combination of two intermittent fountains, similar to the preceding. Let us suppose a similar fountain, the periodical flowing of which is exceedingly quick, that is to say 2 or 3 minutes, and its intermission the same, making altogether an interval of 4 or 5 minutes: let this fountain be fed by another intermittent fountain, placed above it, the duration of the flowing of which is an hour, and the intermittence 2, or 3 or 4: it will thence follow, that the lower one will furnish water only while the upper one sup-

plies it; that is to say, during an hour; and in the course of this hour the lower fountain will have 12 or 15 periods of flowing, interrupted by as many periods of cessation; after which time, as the fountain or pipe E of fig. 31, will not furnish more water for two or three hours, the lower fountain will absolutely cease for one or two or three hours. Here then we have a fountain which will be doubly intermittent, as it will remain a considerable time without flowing, and when it flows it will be intermittent.

REMARKS.—I. With three fountains of this kind, combined together, periods of flowing and intermission, so singular as to appear almost inexplicable, might be produced. But it may be readily conceived, that they would all depend on the same principle.

II. By means of these principles, a fountain to flow continually, but which should become larger and decrease alternately, might be easily constructed. Nothing would be necessary for this purpose, but to combine with the fountain of the preceding problem, a continued fountain: it is evident that it would become larger, when the water flowed through the syphon FGI; and that when it stopped, it would assume its usual state.

If this continued fountain were combined with the double intermittent one of this problem, the result would be a fountain uniform and continued for several hours of the day, and which would afterwards become larger and decrease alternately for an hour.

PROBLEM LXV.

Construction of a fountain which shall cease to flow when water is poured into it; and shall not begin to flow again till some time after.

For this purpose, we must suppose a very close reservoir, half filled with water, as ABCD, pl. 6, fig. 32, havin

a discharging pipe E, some lines only in diameter. This reservoir forms part of another vessel HBFD, in which it is placed; and a portion of the vessel HGF remains empty: IK is a pipe which proceeds from the top of the interior reservoir, nearly to the bottom of the vessel FD; the upper part of the vessel is furnished with a rim, so as to resemble a cup, and the part HG, is pierced with a number of small holes; some moss, with coarse sand, or even grass, must be put into this cup, but in such a manner, that the air may have access through the bottom HG, into the cavity HC.

These things being supposed; let the small reservoir be half filled with water, which will flow out through the discharging pipe E; if water be then poured into the cup at the top, it will fall into the lateral reservoir HC, and close the aperture K of the pipe KI. This aperture being closed, the air contained in that part above the interior reservoir can no longer expand itself: the water flowing through E will fall at first slowly, and at length stop. But if a small pipe be inserted in the corner F, to afford a passage to the water which has fallen into the reservoir HC, when this water is discharged, that at E will again begin to flow.

If water be poured incessantly into the cup HG, and if its escape at F be concealed, this machine will excite great astonishment, as it will seem to flow only when no more water is poured into it.

This machine might be constructed in the figure of a rock, with a fountain issuing from the bottom of it; and the upper part might represent a meadow, or forest, &c. On pouring water over it from a watering pot, to represent rain, the small fountain would be seen to stop, and to continue in that state as long as water was poured over it. The use to which this idea might be applied will be seen hereafter.

PROBLEM LXVI.

To construct a fountain which, after flowing some time, shall then sink down to a certain point; then rise again; and so on alternately.

Though we have not found any thing satisfactory on this subject, it is nevertheless possible; for we shall mention hereafter some instances of fountains, the basons of which exhibit this phenomenon. We shall therefore content ourselves for the present with having proposed the problem to our readers.

REMARKS.

Containing the history and phenomena of the principal intermittent fountains known, as well as of some lakes and wells which have similar properties. History of the famous lake of Tschirnitz.

In the preceding problems we have explained the principles of the phenomena exhibited by a great number of fountains, or collections of water, the properties of which have at all times furnished matter of reflection to philosophers, and been a subject of admiration to the vulgar. But much is to be deducted from what the vulgar relate, or imagine they see, in regard to this subject. Many of these springs, when examined by philosophers, or accurate observers, lose the greater part of what they had of the marvellous. In several of them, however, there still remains enough to exercise the sagacity of the searchers into nature. The object of this work obliges us, in some measure, to make known the most remarkable of these fountains. But we shall confine ourselves to those, the facts respecting which are confirmed by good descriptions; for it is of no utility to repeat what is uncertain or incorrect.

I. The greater part of those springs which originate from

accumulations of ice, are observed to be intermittent. Such are some of those seen in Dauphiné, on the road from Grenoble to Briançon. They flow, as we have been assured, more abundantly in the night than in the day time, which on the first view seems difficult to be reconciled with sound philosophy; but we shall show that this may be explained without much difficulty.

The author of the Description of the Glacieres of Switzerland speaks of a similar spring, at Engstler, in the canton of Berne: it is subject to a double intermittence, that is to say, an annual and a daily: it does not begin to flow till towards the month of May; and the simple peasants, in the neighbourhood, firmly believe that the Deity sends them this spring every year for the use of their cattle, which about that period they drive to the mountains. Besides, like those of which we have already spoken, it is during the night that it flows in the greatest abundance.

The annual reappearance of this fountain, on the approach of spring, may be easily explained: for it is only towards this period that the mass of the earth, being sufficiently heated, begins to melt the ice from below. It is at this period, therefore, that the fountain in question can flow. We make use of the expression from below; for it is in this manner that these enormous masses of ice are melted. No doubt indeed can be entertained of it, when it is observed that they continually give birth to large currents of water, even while their upper surface exhibits the strata of the preceding year scarcely altered. But how comes it that the greater part of these fountains furnish the largest quantity of water in the night time? This phenomenon deserves to be explained.

It arises, in our opinion, from the alternation of heat and cold, occasioned by the presence and absence of the sun, in the mass of the earth covered by this accumulation of ice. But as a certain time is necessary before the heat of

the sun can produce its effect, and be communicated to the distant parts, it happens that the moment of their greatest heat is posterior, by several hours, to that of the greatest heat of the air, which takes place about three in the afternoon: it is only some hours then after sunset, that the greatest liquefaction of the ice, which is in contact with the earth, can be produced: and if we take into consideration the space which the water thence arising must pass through, in confined channels between the valleys and under the ice, it will not seem astonishing that it should not make its appearance till towards night. It will therefore be about eleven o'clock, or midnight, that these streams, produced by the melting of the ice, will furnish the greatest quantity of water.

II. The intermittence in this case depends upon causes which may be easily discovered: it is not even a real intermittence; but the fountains we are about to describe are really intermittent.

A spring of this kind is seen in Fontainebleau, in one of the groves of the Park. It would probably be better known, and would not be inferior in celebrity to that of Laywell, if courts were more frequented by philosophers.

This fountain flows from a sandy bottom, into a bason six or eight feet square: there is a descent to it by several steps, in the last of which, or close to the water, is dug a small channel, which suffers it to run off. The following are the phenomena observed in this fountain:

The bason being supposed to be half full, as is the case when a large quantity of water has been drawn from it, the water rises to the edge of the last step, and runs off by the channel for some minutes. This discharge is followed by a bubbling, sometimes so strong as to be heard at a considerable distance. This is a sign of the speedy falling of the water. It immediately begins, indeed, to fall a few inches below the level of the channel; but this height is

variable. It is then stationary for some time; but afterwards rises; and continues in this manner alternately. Each flux of this kind employs about seven or eight minutes. Sometimes however it seems to sport with the curious, and remains half an hour, or even a whole hour, without repeating the same play.

The description of a fountain, nearly similar to the preceding, may be seen in the Philosophical Transactions, n°. 202 and 424; and in *Desaguliers's* course, vol. II: it is situated at one of the extremities of the small town of Brixham, near Torbay, in Devonshire: the people in the neighbourhood call it Lay-Well. It is on the declivity of a small hill, and distant from the shore a full mile; so that it can have no communication with the sea. The bason, according to the latest description, is eight feet in length, and four feet and a half in breadth. A current continually flows into the bason, and the water escapes at the other extremity, through an aperture, three feet broad, and of a proportionable depth.

Sometimes the water flows uniformly for several hours, without rising or falling; and hence some credulous people believe, that the presence of certain persons has an influence on this fountain, which interrupts its play. But, for the most part, it has a very sensible and very speedy flux and reflux. For about two minutes the water rises some inches, after which it falls for about the same period, and then a short rest ensues; so that the total duration is about five minutes. This takes place twenty times in succession, after which the fountain seems to rest for about two hours, and during that time the water flows in a uniform manner. This, according to the author of the description, is a peculiarity by which this fountain is distinguished from all others that have come within his knowledge. But we have seen that the one at Fontainebleau experiences something of the same kind: a very strong

analogy even is remarked between them, and it appears almost evident from the descriptions, that their periodism is not in the spring, but only in the discharge. This is certain, at least in regard to that of Fontainebleau; as the nature of the ground does not permit us to suppose any thing similar to that which requires a periodical flowing in the spring itself.

However, we shall here describe a third fountain, much more considerable than either of the preceding two, and which presents a very striking intermittence; it is situated in Franche-Comté, and a very good description of it was published in the *Journal des Sçavans*, for October 1688.

This fountain is, or at least was at that period, near the high road leading from Pontarlier to Touillon, at the extremity of a small meadow, and at the bottom of some mountains which hang over it; it flows from two different places, into two basons, on account of the roundness of which it has acquired the name of *la Fontaine ronde*. The upper bason, which is larger than the other, is about seven paces in length, and six in breadth; and in the middle of it there is a stone cut in a sloping form, which serves to render the motion of its reciprocation sensible.

When the flux is about to commence, a bubbling is heard within the fountain, and the water is immediately seen to issue on all sides, producing a great many air bubbles: it rises a full foot.

During the reflux, the water falls nearly the same time, and by the same gradations. The total duration of the flux and reflux is about half a quarter of an hour, including about two minutes of rest.

The fountain becomes almost dry at each reflux, and at the end of it is heard a sort of murmuring noise, which announces its cessation.

The small town of Colmars, in Provence, presents also a fountain of the same kind. It is situated in the neigh-

bourhood of the town, and is remarkable for the frequency of its flux. When it is ready to flow, a slight murmur is heard; it afterwards increases for half a minute, and then throws up a jet of water as thick as the arm; it then decreases for five or six minutes, and stops a short time, after which it again begins to flow. In this manner the duration of its flowing and intermittence together is about seven or eight minutes; so that it flows and stops about eight times in an hour. Gassendi and Astruc have given a more detailed account of this fountain; the former in his works, and the latter in his *Histoire Naturelle de Languedoc et de la Provence.*

The fountain of Fonzanches, in the diocese of Nismes, deserves also to be mentioned. Fonzanches is situated between Sauve and Quissac, not far from, and on the right of the Vidourle. It issues from the earth, at the extremity of a pretty steep declivity, looking towards the east. Its intermittence is very striking: it flows and stops regularly twice in the course of the day, or of twenty-four hours; the duration of its flux is 7 hours 25 minutes, and that of its intermission 5 hours or nearly; so that its flowing is retarded every day about 50 minutes. But it would be erroneous thence to conclude, that it has any connection either with the motion of the moon, or with the sea, though it has been called *la Fontaine au flux et reflux.* It would be absurd to suppose channels proceeding thence to the sea of Gascony, which is 130 leagues distant. Besides, as the retardation of 50 minutes is not exactly that of the tides, or of the moon's passage over the meridian, the analogy of the one movement with the other can no more be maintained, than if this retardation were much greater or less.

We shall terminate this paragraph with a description of the famous fountain called *Fontestorbe*, situated in the diocese of Mirepoix. The account we shall give of it is ex-

tracted from Astruc's description, published in the work before mentioned.

Fontestorbe is situated at the extremity of a chain of rocks, which advance almost to the banks of the river Lers, between Fougas and Bellestat, in the diocese of Mirepoix. At a considerable height above the bed of the river is a cavern, 20 or 30 feet in length, 40 in breadth, and 30 in height. On the right side of this cavern is the fountain in question, in a triangular aperture of the rock, the base of which is about eight feet in breadth. It is through this aperture that the water issues, when the flux takes place. What characterises its intermission, in a very singular manner, is, that it is intermittent only during the time of drought; that is to say, in the months of June, July, August, and September: it then flows for 36 or 37 minutes, rising 4 or 5 inches above the base of the triangular aperture, after which it ceases to flow for 32 or 33 minutes. If it happens to rain, the time of intermission is shortened, and when it has rained three or four days in succession, it becomes annihilated; so that the fountain then continues, though with a periodical increase: but at length, when the rain has lasted a considerable time, the flux is continued and uniform, and remains in this state throughout the winter, until the return of dry weather, when the fountain again becomes periodical and intermittent; by the same gradations inverted.

The reason of the greater part of the phenomena here described may be deduced from the principles explained in the preceding problems. For this purpose, nothing is necessary but to conceive a cavity of greater or less extent, formed by the sinking down of a bank of clay, and which serves as a reservoir to a collection of water, furnished by a spring. Let this cavity have a communication outwards by a kind of crooked channel, the interior aperture of which is near the bottom of the cavity, and the exteri-

one much lower: this channel will evidently perform the part of the syphon of Prob. LXIII, fig. 31, and will produce the same phenomena, supposing however that the exterior air has access to the cavity.

If the spring then which fills the cavity here described always furnishes less water than the supposed syphon can evacuate, the water will flow only periodically; for before it can issue, it must rise to the summit or angle of the two branches of the syphon: it will then flow and evacuate the water contained in the cavity, and it will again stop till more water rises.

But, if the concealed spring, which feeds the reservoir, be variable, that is to say if it be much more abundant in winter, and during rainy weather, than in summer, or during dry weather, the apparent spring will be intermittent only during the latter; the duration of its intermissions or rest will decrease, according as the concealed spring becomes more abundant, and when the concealed spring gives as much water as the syphon can evacuate, the apparent spring will become continued: it will at length gradually resume its intermittence, according as the interior spring decreases in volume.

Here then the phenomena of the spring of Fontestorbe are explained, by the same mechanism as that of the other springs purely intermittent. It appears, that in the latter the concealed spring derives its origin from subterraneous water, which receives little or no augmentation from exterior water; and that, on the contrary, the spring of Fontestorbe is fed by water arising from rain and melted snow.

We shall add only a few words more, respecting some fountains of this kind, mentioned in various authors. Such is that in the environs of Paderborn, called Bullerborn, which flows, it is said, for twelve hours, and rests during the same period: that of Haute-Combe, in Savoy, near the

lake of Bourget, which flows and stops twice in an hour: that of Buxton, in the county of Derby, mentioned by Childrey in his *Curiosités d'Angleterre*, which flows only every quarter of an hour: one near the lake Como, celebrated in the time of Pliny the younger, which rises and falls periodically, three times a day: &c.

III. We shall now describe phenomena of another kind, namely, those exhibited by certain wells or springs, which rise and fall at certain periods, while no place is known by which the water is discharged. There is a well near Brest subject to this periodical falling and rising, the explanation of which has afforded considerable occupation to philosophers. The description we shall give of it is extracted from the Journal de Trevoux, October 1728: it was written by Father Aubert, a Jesuit, who appears to have been a very correct and well informed philosopher.

This well is situated at the distance of two leagues from Brest, on the border of an arm of the sea, which advances as far as Landernau. It is 75 feet from the edge of the sea at high water, and nearly double that distance at low water. It is 20 feet in depth, and its bottom is lower than the surface of the sea at high water, but higher than the same surface at low water.

It would not be astonishing, or rather would be altogether in the natural order of things, if the well should sink down at low water, and rise at high water; but the case is quite contrary, as will be seen by the following detailed account of the phenomena observed.

The water of the well is lowest, that is to say is only 11 or 12 inches above its bottom, when the sea is at its highest. It remains in that state about an hour, reckoning from the time of high water; it then increases for about two hours and a half, during the time the sea is ebbing; after which it remains stationary for about two hours. It then begins to decrease for about half an hour before the tim

of low water, and this continues for the first four hours of the sea's flowing. In the last place, it remains in the same state of falling for about three hours, that is during the last two hours of the sea's rising, and the first hour of its ebbing; after which it again begins to rise, as before mentioned. It was observed during the great drought, in the year 1724, that this well was for some hours dry, while the sea flowed, and that it became full as the sea ebbed. We do not know whether this well be still in existence. What adds to the singularity of the phenomenon is, that the neighbouring wells, which might be supposed to experience the same vicissitudes, are subject to nothing of the kind.

According to Desaguliers, a small lake at Greenhithe, between London and Gravesend, exhibits the same phenomena: and this author adds, that he heard at Lambourn, in Berkshire, of a spring which is full in dry weather, and dry during rainy weather. It is much to be wished that he had ascertained the truth of these circumstances.

IV. But every thing hitherto said, though very remarkable, is nothing when compared with the singularity of the famous lake of Tschirnitz. This lake, which is of considerable extent, is situated near a small town of the same name, in Carniola. It is about three French leagues in length, and one and a half in breadth, having a very irregular form.

The singularity of this lake consists in its being full of water during the greater part of the year; but towards the end of June, or the first of July, the water runs off by eighteen holes or subterranean conduits, so that what was the abode of fish and abundance of aquatic fowls, becomes the haunt of cattle, who repair thither to pasture on the grass which is found there in great plenty. Things remain in this state for three or four months, according to the constitution of the year; but after that period, the

water returns through the holes by which it had been absorbed, and with so considerable a force that it spouts up to the height of several feet, so that in less than twenty-four hours the lake has resumed its former state.

It is however to be observed, that there are some irregularities in the time and duration of this evacuation. It sometimes happens that the lake is filled and emptied two or three times in the year. One year it experienced no evacuation, but it never remained empty above four months. Notwithstanding these irregularities, the phenomenon deserves a place among the most extraordinary singularities of nature. See on this subject a work by M. Weichard Valvasor, a learned man of that country, entitled *Gloria ducatus Carniolæ, &c*, 1688, 4to. This author enters into details which entitle him to credit; and besides this, it is a fact well known, and mentioned by various intelligent travellers.

M. Valvasor deduces, with great probability, the phenomena of this lake from subterranean cavities, which communicate with it, by the apertures already mentioned, and which are full of water supplied by the rain. When the rain ceases for a considerable time, so that the water is evacuated by a certain point, a play of syphons takes place, by which means the whole lake is emptied. But for the details of this explanation we must refer to the work before mentioned, or to the acts of Leipsic for the year 1688.

PROBLEM LXVII.

Of the speaking trumpet, and ear trumpet: Explanation of them: Construction of the inchanted head.

As the sight is assisted by telescopes and microscopes, so similar instruments have been contrived for assisting the faculty of hearing. One of these, called the speaking trumpet, is employed for conveying sound to a great

distance: the other, called the ear trumpet, serves to magnify to the ear the least whisper.

Among the moderns, Sir Thomas Moreland bestowed the most labour in endeavouring to improve this method of enlarging and conveying sound, and on this subject he published a treatise, entitled *De Tuba Stento ophonica,* a name which alludes to the voice of Stentor, so celebrated among the Greeks for its extraordinary strength. The following observations on this subject are in part borrowed from that curious work

The ancients, it would seem, were acquainted with the speaking trumpet: for we are told that Alexander had a horn, by means of which he could give orders to his whole army, however numerous. Kircher, on the authority of some passages in a manuscript, preserved in the Vatican, makes the diameter of its greatest aperture to have been seven feet and a half. Of its length he says nothing; and only adds that it could be heard at the distance of 500 stadia, or about 25 miles.

This account is no doubt exaggerated; but however this may be, the speaking trumpet is nothing else than a long tube, which at one end is only large enough to receive the mouth, and which goes on increasing in width to the other extremity, bending somewhat outwards. The aperture at the small end must be a little flattened to fit the mouth; and it ought to have two lateral projections, to cover part of the cheeks. All this will be better comprehended by recurring to pl. 6 fig. 33, which requires no farther explanation.

Sir Thomas Moreland says, that he caused several instruments of this kind to be constructed of different sizes, viz, one of four feet and a half in length, by which the voice could be heard at the distance of 500 geometrical paces; another 16 feet 8 inches, which conveyed sound 1800

paces; and a third of 24 feet, which rendered the voice audible at the distance of 2500 paces.

To explain this effect, we shall not say, with Ozanam, that tubes serve, in general, to strengthen the activity of natural causes; that the longer they are the more this energy is increased, &c; for this is not speaking like a philosopher; it is taking the effect for the cause: we must reason with more precision.

The cause of this phenomenon is as follows. As the air is an elastic fluid, so that every sound produced in it is transmitted spherically around the sonorous body; when a person speaks at the mouth of the trumpet, all the motion which would be communicated to a spherical mass of air, of four feet radius, for example, is communicated only to a cylinder, or rather cone of air, the base of which is the wider end of the trumpet. Consequently, if this cone is only the hundredth part of the whole sphere of the same radius, the effect will be as great as if the person should speak a hundred times as loud in the open air: the voice must therefore be heard at a distance a hundred times as great.

The ear trumpet, an instrument exceedingly useful to those almost deaf, is nearly the reverse of the speaking trumpet: it collects, in the auditory passage, all the sound contained within it; or it increases the sound produced at its extremity, in a ratio which may be said to be as that of the wide end to the narrow end. Thus, for example, if the wide end be 6 inches in diameter, and the aperture applied to the ear 6 lines, which in surfaces gives the ratio of 1 to 144, the sound will be increased 144 times, or nearly so; for we do not believe that this increase is exactly in the inverse ratio of the surfaces: and it must be allowed that, in this respect, acoustics are not so far advanced as optics.

Remark.—It is a certain fact, proved by experience, whatever may be the cause, that sound confined in a tube is conveyed to a much greater distance than in the open air. Father Kircher relates, in some of his works, that the labourers employed in the subterranean aqueducts of Rome heard each other at the distance of several miles.

If a person speaks, even with a very low voice, at the extremity of a tube, some inches in diameter, another who has his ear at the other extremity will hear distinctly what is said, whatever be the number of the circumvolutions of the tube.

This observation is the principle of a machine, which excites great surprise in those unacquainted with the phenomena of sound. A bust is placed upon a table; from one or each of its ears a tube is conveyed through the table and one of its feet, so as to pass through the floor, and to end in a lower or lateral apartment. Another tube, proceeding from the mouth, is conveyed in a similar manner, into the same apartment. A person in company is desired to ask the figure any question, by whispering into its ear. A confederate of the one who exhibits the machine, by applying his ear to the extremity of the first tube, hears very plainly what has been said; and placing his mouth at the aperture of the other tube, returns an answer, which is heard by the person who proposed it. If motion be communicated at the same time to the lips of the machine, by any mechanical means, the ignorant will be much surprised, and inclined to believe that this phenomenon is the effect of magic. It may be easily seen, however, that the cause is very simple.

PROBLEM LXVIII.

When boys play at Ricochet, or duck and drake, what is the cause which makes the stone rise above the surface of the water, after it has been immersed in it?

This play is well known, as most boys amuse themselves with it, when near a piece of water of any extent. But the cause why the stone rebounds, after it has touched the surface of the water, seems to be involved in a certain degree of obscurity; and we will even say that some philosophers have mistaken it, by ascribing it to the elasticity of the water. As water has no elasticity, it is evident that this explanation is not well founded.

This rebounding however depends on a cause which approaches very near to elasticity. It is the effort made by every column of water, depressed by a shock, to rise up and resume its former situation, in consequence of a sort of equilibrium which must prevail between it and its neighbours. But let us enter into a more detailed analysis of what takes place on this occasion.

When the stone, which must be flat, is thrown obliquely at the surface of the water, and in the direction of its edge, it is evident that it is carried by two kinds of motion compounded together, one horizontal, which is quicker, and the other vertical, which is much slower. The stone, when it reaches the surface of the water, impels it by the effect of the latter only, and depresses a little the column of water which it meets; this produces a resistance which weakens the vertical movement, but without destroying it; so that it continues to dip, depressing other columns; hence there result new resistances, which at length annihilate this motion, so far as it is vertical. The stone has then reached the greatest depth to which it can attain, and must necessarily describe a small curve, the convexity of

which is opposite to the bottom of the water, as seen pl. 6, fig. 34; but, at the same time, its motion so far as it is horizontal has lost little or nothing. On the other hand, the column, depressed by the shock of the stone, re-acts against it, being pushed by the neighbouring columns; and hence there arises a vertical motion communicated to the stone, which is combined with the remaining part of its horizontal motion. The result then must be an oblique motion, tending upwards; which causes the stone to rebound above the water, making it describe a very much flattened small parabola; it then again strikes the water obliquely, which produces a second rebounding; then a third, a fourth, and so on, always decreasing in extent and height, till the motion is entirely annihilated.

PROBLEM LXIX.

Mechanism of paper Kites: Various questions in regard to this amusement.

Every one is acquainted with the amusement of the paper kite, a very curious small machine, which in its mechanism displays great ingenuity. To some however it may appear astonishing that an object of this nature should form the subject of an academic memoir; for there is one on paper kites in the Transactions of the Academy of Berlin for the year 1756. But this surprise will cease when it is known, that Mr. Euler junior was a profound geometrician, at an age when most young persons see nothing in the paper kite but an object of amusement: to him therefore it could hardly fail of being a subject of meditation. It presents indeed several curious questions, and which for the most part cannot be treated without the higher analysis. This memoir therefore may be ranked among the *juvenilia* of a great mathematician. We shall not follow him in his profound calculations; we shall con-

tent ourselves with treating the subject in a less rigorous manner, but much easier to be understood.

The kite, as is well known, is a plane surface, ABCD, pl. 6 fig. 35, as light as possible, shaped like an irregular rhombus; that is to say, formed of two triangles BAC, and BDC, in which the angle A of the former is much greater than the angle D of the latter. The head is towards A, and D is the tail, to which is generally affixed a long cord, having pieces of paper attached to it at certain lengths: some much shorter are placed at the corners B and C, which causes the small machine, when elevated, to appear at a distance like a monstrous bird balancing itself in the air, by the help of its tail and its wings.

At a point of the axis AD, and towards the point E, is affixed a small cord, some hundreds of feet in length, rolled upon a stick, to be let out or taken in as occasion may require. But it is necessary that this cord should be made fast to the kite in a certain manner; for, in the first place, two other small cords proceeding from a point near the place where it is attached must be extended to the points B and C, to prevent the machine from turning on the axis AD; and secondly, from the same point of the cord, another small cord must proceed to a point near the head A; so that the angle formed by the cord with the axis AB shall be acute towards A, and invariable: a fourth even is made to proceed from this point of the cord to a point near D.

These arrangements being made; when the kite is to be committed to the wind, an assistant holds the cord at the distance of some yards, and the inferior surface of the kite being exposed to the wind, it is thrown up into the air. The person who holds the cord then begins to run against the wind in order to increase the action of the air on its surface. If a considerable resistance is experienced, a little of the cord is successively unrolled, and the kite

rises: it is necessary to know how to govern it by unrolling or winding up the cord properly; that is to say, letting it go when it is found by the effort experienced that the kite can still rise, and winding it up when it becomes slack. A kite properly constructed, when the time and place are favourable, can rise to the height of three or four hundred feet, and even more.

To analyse this amusement, and explain what takes place, let us suppose that AD pl. 6 fig. 36, represents the axis of the kite, to which is attached the cord EC, held at C by the person who directs it. Let FE be the direction of the wind, all the currents of which we suppose united in one, acting on the centre of gravity of the surface of the kite; and which, for the sake of simplifying, we shall suppose not to differ from that of the body itself, or to be very near it.

Let FE represent the force with which the wind, to which the kite is exposed, impels its surface in a perpendicular direction; draw EG perpendicular to that surface, and make EL a third proportional to EF and EG, and draw LM, parallel to GF; EL will represent the force with which the wind impels the lower surface of the kite, in the perpendicular direction, and LM will be the effort exercised by this impulse in the direction ML or AED.

We shall first observe, that by the latter the kite would tend to be precipitated downwards; but the angle AEC being acute, there thence results an effort in the direction EA, which counterbalances the former; otherwise the kite could not support itself, and this is the reason why this angle must necessarily be acute.

If we now make EH equal to EL, and draw EI perpendicular to the horizon, and HI perpendicular to EH, we shall have two new forces; one of which, IH, will act in the direction ED, and tend to throw down the kite: but this force is annihilated, as well as the former ML, by the

power in C, which draws according to the acute angle AEC. The other, EI, is that which tends to make the kite rise in a vertical direction.

Hence, if the force EI be greater than the weight of the kite, it will be raised into the air; and if we suppose that the extremity of the cord is fixed in C, it will turn around the point C as it rises; but by turning in this manner it must necessarily happen, that the wind will fall with more obliquity on its surface AB; so that there will at length be an equilibrium. The kite then will rise no farther, unless the cord is let out; in which case it will rise parallel to itself, and as in ascending it will meet with freer air and a stronger wind, it will still turn a little around the angle C; or the angle C will become greater, and approach more and more to a right angle.

Such is the mechanism by which the paper kite rises into the air. It may be readily seen, that if the velocity of the wind, with the surface and weight of the kite, be known, as well as the constant value of the angle AEC, the height to which it will rise may be determined.

A question, which here naturally presents itself, is, what ought to be the quantity of the angle AEF, in order that the small machine may rise with the greatest facility? We shall not give the analysis of this question, but shall only say, that if the wind be horizontal, this angle must be 54° 44′, or the same which the rudder of a ship ought to make with the keel, that the vessel may be turned with the greatest facility, supposing the currents of water which impel it to have a direction parallel to the keel.

We shall here observe, that it is not absolutely necessary that the angle AEC should be invariable, and determined to be such, by a small cord proceeding from a point of CE to another point near the head; but in this case the point E, where this cord is attached to the kite, must not be the same as the centre of gravity of the surface of the kite, and

the centre of gravity must be as far as possible towards the centre of the tail D. It is for this reason, that a cord with bits of paper fixed in it is added to the point D; by which means the centre of gravity is thrown towards that point. Those who amuse themselves with kites were certainly not conducted to this mode of construction *à priori:* the origin of this appendage must have been a desire to give to the small machine the appearance of a bird with a long tail, balancing itself in the air. But accident, on this occasion, has been of great utility; for M. Euler found by a calculation, of which no idea can be here given, that this small tail contributes a great deal to the elevation of the kite.

In short, this amusement, however frivolous it may appear, presents some other mechanical considerations which require a great deal of address, and a very intricate calculation; but for farther particulars, we must refer to the Memoir of Mr. Euler before mentioned.

REMARK.—By observing the before-mentioned rules, various figures may be given to this small machine; such as that of an eagle, or a vulture, &c. We remember to have once seen a kite which resembled a man. It was made of linen-cloth cut, and painted for the purpose, and stretched on a light frame, so constructed as to represent the outline of the human figure. It stood upright, and was dressed in a sort of jacket. Its arms were disposed like handles on each side of its body, and its head being covered with a cap, terminating in an angle, favoured the ascent of the machine, which was 12 feet in height; but to render it easier to be transported, it could be folded double by means of hinges adapted to the frame. The person who directed this kind of kite was able to raise it, though the weather was very calm, to the height of nearly 500 feet; and, when once raised, he maintained it in the air by giving only a slight motion to the string The

figure, by these means, acquired a kind of libration like that of a man skaiting on the ice. The illusion occasioned by this spectacle, which might seem fit only for amusing school-boys, did not fail to attract a great number of curious spectators.

PROBLEM LXX.

Of the Divining Rod; and opinion which we ought to form of it.

We shall speak here of the divining rod, merely because this illusion, or philosophical quackery, made at one time a great noise, and because the reader will doubtless expect to find some account of it in a work of this kind: were not this the case, such idle dreams would be too contemptible, and too unworthy of the philosophy of the present century to deserve notice.

The divining rod is nothing else than a forked piece of hazel, the two branches of which must be 15 or 18 inches in length, and form an angle of 30 or 40 degrees. The two branches are held in the hands in a certain manner, so that the trunk or middle is turned towards the heavens*. Some persons, it is said, are endowed with such a property, that if they hold this rod as above described, it tends by a violent effort to turn its trunk downwards †, when in the proximity of a spring, or of precious metals concealed in the bowels of the earth, or stolen money, &c. Nay, some even have asserted that it has pointed out, in this manner, the traces of criminals, robbers, or assassins. An instance of this credulity, too memorable to be omitted, took place at Lyons, in consequence of a murder committed on the 5th of July 1692. A retailer of wine and his wife were both found murdered, as appeared, by blows

* Other accounts say down towards the earth.

† Or upwards.

with a hedging bill, and their money was carried away from a shop in which they usually resided. As no traces were found of the assassin, recourse was had to James d'Aymar, a native of Dauphiné, who about that period had acquired great reputation and many partisans, by means of his divining rod. D'Aymar having caused himself to be conducted to the spot where the murder had been committed, was scarcely entered, when he fell into a sort of a fit. As soon as he had recovered, after making a thousand contortions and movements with his rod, he promised to follow the track of the assassins. He took the rod in his hand, and, accompained by a clerk of the police and some horsemen of the Marechaussée, proceeded to Beaucaire, pursuing the same route which he said the assassins had taken. When he arrived at that city, still guided by his rod, he went straight to the gate of the prison, in which it was customary to confine thieves during the time of the fair. On the gates being opened, twelve or fifteen prisoners were presented to him, but the rod turned only to a hump-backed person, who had been caught in the act of thieving. He was conducted to Lyons, confessed his crime, and was broken on the wheel in the place des Torreaux.

The assassin, before he expired, confessed that there were two accomplices, who had been with him at Beaucaire, and who had quitted that city when they heard of his being arrested; but that he did not know whither they were gone. "I shall find them dead or alive," said d'Aymar; and again taking his rod, proceeded to Beaucaire, with the same escort as before. When he arrived at the town, he asserted that the assassins had directed their course to Toulon; he pursued them thither, but at Toulon his rod indicated that they had embarked: a vessel was sent in search of them; but they were not found, and d'Aymar and his companions returned to Lyons.

figure, by these means, acqui to d'Aymar's reputation.
of a man skaiting on the ice that he could have traced
this spectacle, which mi d, had it been lawful to arrest
school-boys, did not fail to All these facts, and a great
ous spectators. rising, were submitted to the ex-
The public wished to know,
whether they could be explained
Of the Divining Rod manner as the motion of the mag-
two poles. Malebranche, naturally
We shall speak them without distinction, and after
this illusion, or ph concluded, that they could be explain-
a great noise, and xplicit, or at least implicit, compact with
to find some acco from Lyons, d'Aymar proceeded to Paris,
this the case, such invited by the prince of Conti, who was
and too unworth having an opportunity of being a witness to
to deserve notice the rod which he employed. The prince
The divining to the terrace of Chantilly, made him take his
hazel, the t hand, and expected that it would turn speedily,
in length, as the river passes below the terrace. This however
two branch the case; for the rod, in whatever manner dis-
so that the still remained motionless. The prince caused gold,
Some pers and flints, to be concealed in four different places
perty, of his gardens, and the rod, accustomed to indicate
tends bags, turned only to the bag filled with flints, and placed
when considerable depth in the earth. The prince having
conce informed that an *archer de guet* had been assassinated
Nay, the rue St. Denis, repaired thither, accompanied by the
this king's advocate and d'Aymar. After care had been taken
An to blindfold him, he was carried several times past the
too place where the murder had been committed, and though
mit it was covered with blood, the rod still remained motion-
bi less. D'Aymar was therefore expelled as a cheat and im-
postor. It does not appear that he was ever after em-
ployed in the southern countries, to pursue criminals who
had fled; for we do not find a single word respecting this

man in the history of that period: it is even said that, notwithstanding his celebrity, he died in misery. There is reason to think that he had been a witness of the crime committed by the two villains at Lyons, and that being desirous to acquire a great name in the art of directing the divining rod, he followed them to Beaucaire, being acquainted with their project of remaining there during the fair; that he returned speedily to Lyons to announce his secret, and in this manner had followed their track. We must consider as mere fables the other circumstances added, such as, that he knew the glasses from which they had drunk, the knives they had used, and other things of the like kind.

How could rational minds imagine that an action morally bad could communicate any physical quality to the authors of it? That the murderer of a human being, or stolen money, should have an effect on the rod, rather than the person who had killed a sheep, or money merely displaced? Those who can believe in such reveries must be exceedingly weak.

Some philosophers, equally credulous, have confined the property of the divining rod to turning in the proximity of treasures; that is to say, considerable masses of gold or silver, or to fountains or collections of water, &c. In the same manner, say they, as the magnet exercises an action on iron, by invisible particles, these bodies, by a peculiar emanation, may exercise an action on the wood of the rod, or the arms of the person who employs it; &c. All this fine reasoning, and much more, may be seen in a work called *la Baguette devinatoire*, by the abbé Vallemont; a man not destitute of knowledge, but credulous, and ready to adopt every thing connected with the marvellous.

Father Kircher also, another celebrated man, but no less fond of the marvellous, and often a dupe to his credulity, has endeavoured to reconcile the pretended wonders of the

divining rod, with the principles of sound philosophy. Thus, for example, he formed a straight rod, one half consisting of rock salt, and the other of wood, which he placed in equilibrium, and having exposed it to the vapour of a warm solution of marine salt, observed that the saline half inclined downwards; from which he concluded, that such a rod, if carried above a mine of salt, might point it out by losing its equilibrium. This was wretched reasoning; for salt mines do not exhale vapours like hot water; but even if we suppose this to be the case, pure water also forms such vapours, and Kircher would have experienced the same thing if he had exposed his compounded rod to the vapour of pure water. But it would be losing time to discuss such ridiculous notions, which are entertained only by a few credulous minds, misled by impostors.

In the same class ought to be placed the pretended wonders of one Parangue, much boasted of some years ago in the southern provinces of France, who was endowed, it is said, with the wonderful property of seeing springs in the bowels of the earth, and even at a great depth: he could trace out their course, and tell nearly at what depth they were. Every day announced some new fact, which attested this wonderful faculty; and books were written, in which the authors endeavoured to explain how it was possible that his eyes could penetrate to the bowels of the earth; for to render this faculty still more wonderful, it was believed that he really saw subterranean objects in the full extent of the term. But this impostor had not the same honour as d'Aymar; he was not invited to Paris; he was suffered to perform his wonders in the province where he was born; but he soon lost his reputation there, as well as in the neighbouring provinces. The place where he performed his greatest miracles was Montelimart; where the magistrates were led into considerable expence, in consequence of their trusting to the

word of Parangue, who made them dig to considerable depths to find water, but without success. The partisans of the impostor said, that they were too soon discouraged, and that they would have certainly found water had they continued. This we believe; and if prophecies be understood in this manner, they cannot fail to be verified.

We have heard of another impostor in the same country, who pretended to discover concealed water in a different manner. He walked over the places where water was supposed to exist, and was always attacked by violent illness till he had passed the spring; *Credat Judæus Apella.*

It would appear that the folly of man is endless. About the year 1788, a woman was seen at Lisbon possessed of a much more extraordinary property. At the age of five years she saw a child in the belly of the cook, and with great simplicity told her mother of it. The event, it is said, justified the girl, whose talents always continued to improve. When she attained to a certain age, she could see into the human body, as if it had been transparent, and even pointed out to the physicians the viscera attacked by disease. One thing however very remarkable was, that she could not see into the human body in this manner, except when it was naked. But though light clothing intercepted the view of what was beyond it, she could see, it is said, to a very great depth in the earth. In like manner, Parangue, who could see through rocks, could not see through a board. In regard to the wonderful lady of Lisbon, she saw exceedingly well, and even read, through a plank, an inch in thickness. Walking one day when a child, she saw a mine below the earth; and it was indeed found that there existed one at the depth of 60 fathoms. It may be readily conceived that she saw subterranean water and springs; and it is pretended that there are a great many wells at Lisbon, which were dug according to her indications. To her also was owing, it

is said, the discovery of an obelisk, long concealed under the earth, and which was erected as a decoration to the city.

It is related also, that an ecclesiastic of that capital could, at all times, discover the presence of subterranean water, by looking towards the sun at noon. He saw, it is said, a column of vapour rising towards that luminary.

All these ridiculous tales may be seen in a work entitled *Memoires instructifs pour un Voyageur;* Amst. 1738: they were compiled by the admirers of the impostor of Montelimart in order to prove, that what is related of the latter was not impossible; but they did not perceive that they were attempting to prove one absurdity by a greater.

But how can sound reasoning be expected from people who consider it as a fact that the fountain of Cintra, in Portugal, emits a ray of light, which proceeds in a straight line towards the sun; that those afflicted with the jaundice will be cured, if they see the bird called *Loriot;* that a furious elephant becomes immediately calm when he sees a sheep; and many other things of the like kind? Such people are capable of believing that one can see without light; and it may be said of them, that though they have eyes, as well as light, they do not see, at least with the eyes of the understanding.

REMARK.—Notwithstanding the incredulity above expressed by Montucla, relative to the indication of springs by the motion of the baguette, or divining rod; there appears to exist such evidences of the reality of that motion, as it seems next to impossible to be questioned. The editor of this edition, in common with many other persons, notwithstanding the numerous accounts of that motion which have been published to the world, and attested by multitudes of eye-witnesses, was still incredulous, and remained satisfied that there must have been some trick used in making the experiment, by which the

spectators might be deceived, and imposed on. But, since the publication of the former edition of this translation, such evidence of the motion in question has been exhibited as leaves little or no doubt on the minds of all the spectators as to the reality of that motion. This evidence was brought about in the following manner. Soon after the publication of the said former edition of these Recreations, the editor received, by the post, the following well-written pseudonymous letter, on the subject of this problem.

"Sir, Feb. 10, 1805.

"Having lately read in your translation of Montucla's Recreations the article respecting the *Divining Rod*, I am tempted to trouble you with an account of the *Real Powers* it may possess. From the character I have universally heard of your candour, I am inclined to think you will place confidence in what I shall relate; it may also afford you some amusement, and should you, from reflecting on the *Facts*, discover the *Cause*, it would be a great gratification to me to be informed of your discovery.

"I have perused the history of La Baguette Divinatoire; in that book much superstition and fable are blended with the simple truth: natural philosophy had made but little progress at the period that book was written, and they joined together things which had no other connection than from erroneous ideas: even in these more enlightened days the absurdity of animal magnetism, founded on some allusion to the real magnet, has found partizans and believers; yet that folly cannot shake the conviction of the influence of the magnet, though not yet I believe satisfactorily accounted for.

"In the year 1772 (I was then 19) I passed six months at Aix in Provence: I there heard the popular story of one of the fountains in that city having been discovered some

generations before, by a boy who always expressed an aversion from passing one particular spot, crying out *there was water.* This was held by myself, and the family I was with, in utter contempt, and believed as much as the tradition of this county, that St. Dunstan's head rolled to the spot where Durham abbey was to be built and dedicated to him.

"In the course of the spring the family went to pass a week at the chateau D'Ansouis, situated a few miles to the north of the Durance, a tract of country very mountainous, and where water is ill supplied. We found the marquis D'Ansouis busied in erecting what might be termed a miniature aqueduct, to convey a spring the distance of half a league, or nearly that distance, to his chateau, which spring he asserted had been discovered by a peasant, who made the discovery of water his occupation in that country, and maintained himself by it, and was known by the appellation of *l'homme à la Baguette:* his real name has escaped my recollection; but you will find some account of him in one of the Annual Registers near the period I have named, I believe that of 1772*; but not at present having the books to refer to, I cannot ascertain the year.

"This account was received with unbelief, almost amounting to derision. The marquis, piqued at being discredited, sent for the man, and requested we would witness the experiment. A large party of French and English accordingly attended. The man was quite a peasant in manners and appearance: he produced some twigs cut from a hazel of different sizes and strength, only they were the forked branches, and hazel was preferred as forking more equally than most other trees; but it is not requisite that the angle should be of any particular

* It is at p. 96, pt. 2, of that year. Editor.

number of degrees. He held the ends of the twigs between each fore fingers and thumbs, with the vertex pointing downwards. Standing where there was no water, the baguette remained motionless; walking gradually to the spot where the spring was *under ground*, the twig was sensibly affected; and as he approached the spot, began to *turn round;* that is, the vertex raised itself, and turned towards his body, and continued to turn till the point was vertical; it then again descended outwards, and continued to turn describing a circle, so long as he remained standing over the spring, or till one or both the branches were broken by the twisting, the ends being firmly grasped by the fingers and thumbs, and the hands kept stationary, so that the rotary motion must in course twist them. After seeing him do this repeatedly, the whole party tried the baguette in succession, but without effect. I chanced to be the last; no sooner did I hold the twig as directed, than it began to move as with him, which startled me so much that I dropt it, and felt considerably agitated. I was however induced to resume the experiment, and found the effect perfect. I was then told it was no very unusual thing, many having that faculty, which, from what has since come to my knowledge, I have reason to believe is true. On my return to England I forbore to let this faculty (or whatever you may term it) be known, fearing to become the topic of conversation or discussion. But, two years afterwards, being on a visit to a nobleman's house in Huntingdonshire, and his lady lamenting that she was disappointed of building a dairy-house in a spot she particularly wished, because there was *no water* to be found, a supply she looked on as essential; under *promise of secrecy* I told her I would endeavour to find a spring. I accordingly procured some hazel twigs, and, in the presence of herself and husband, walked over the ground proposed, till the twig turned with *considerable force*. A

stake was immediately driven into the ground to mark the spot, which was not very distant from where they had before sunk. They then took me to another, and distant building in the park, and desired me to try there: I found the baguette turn *very strong*, so that it soon twisted and broke: the gentleman persisted that there was no water there, unless at a great depth, the foundation being very deep (a considerable stone cellar) and that no water appeared when they dug for it. I could only reply, that I have no more than from the baguette turning, and that I had too little experience of its powers or certainty to answer for the truth of its indication. He then acknowledged that when that building was erected, they were obliged to drive piles for the whole foundation, as they met with nothing but a quicksand. This induced him to dig in the spot I first directed; they met with a very fluent spring; the dairy was built, and is at this time supplied by it. I could give a long detail of other trials I have made, all of which have been convincing of the truth, but they would be tedious. For some years past I have been indifferent about its becoming known, and have consequently been frequently requested to show the experiment, which has often been to persons in high estimation for understanding and knowledge, and I believe they have *all been convinced*. Three people I have met with who have, on trying, found themselves possessed of the same faculty. I shall only add one more particular incident: having once shown it to a party, we returned into the house to a room on the ground floor; I was again asked to show *how I held the twig;* taking one in my hand I found it turned immediately; on which an old lady, mother to the gentleman of the house, said *that room* was formed out of an old cloister, in which cloister was a *well*, simply boarded over when they made the room.

" L'homme à la baguette from experience, could with

tolerable accuracy tell the depth at which the springs were, and their volume, from the force with which the baguette turns; I can only give a rough guess. In *strong frost* I think its powers not so great; on a bridge or in a boat it has *no effect;* the water must be *under ground* to affect the baguette, and running through wooden pipes acts the same as a spring; even being *arched* over does not prevent it, as I felt a spring broke out in a cellar, standing in a stone passage over the arch. I can neither make the baguette turn where there is *no water*, nor prevent it from turning where there *is* any, and I am perfectly ignorant of *the cause why it turns.*

"The only sensations I am sensible of, is an emotion similar to that felt on being startled by sudden noise, or surprise of any kind. If, sir, you can throw any light on this fact, and account for it, I hope you will indulge me by communicating your conjectures. A letter under cover to ———— near ————, directed to X. Y. Z. will by him be forwarded to me. If you should think it worth your trouble to make any queries on the subject, I will with pleasure reply to them.

"I am, Sir,

"your humble servant, and admirer of your talents,

"X. Y. Z."

Having in reply made a suitable acknowledgment for the favour of this letter, with expressions of surprize at the extraordinary account it contained, and a declaration of my ignorance of any cause in nature to produce such alleged effects, but a wish for further information and evidence. In consequence I was afterwards favoured with the following letter from the same writer, a lady of elevated rank, whose high character for talents and accomplishments I was, by general report, well acquainted with.

"Sir,

"I have received your letter directed for X. Y. Z. in reply to one bearing that signature of Feb. 10, 1805.

"The candid manner in which you have considered the narrative I then sent demands an acknowledgment. I withheld my name, more from a wish that you might openly state any doubts you might entertain, than from any wish to conceal it, as otherwise you might have felt some delicacy in expressing disbelief. I lament you can throw no light on this extraordinary circumstance, which has ever strongly excited my curiosity as to the cause of it, but hitherto I have met with none who have gone beyond a vague conjecture. A very sensible and well informed physician *imagined* it might be occasioned by some singular effect of electricity on my frame, but could not satisfy himself of the certainty of his conjecture. I shall most probably be in London next winter, and will (if you wish it) afford you an opportunity of making your own observations on this curious fact, which you may then give any account of that you please, either in the next edition of your Montucla, or any other publication.

"The nobleman's house I named in my letter was Kimbolton, and I make no doubt that the present dowager duchess of Manchester well remembers the experiment and its success.

"I could refer you to many of the first characters in the kingdom who have seen it tried at different times and different places, but am inclined to be of opinion that you will not suspect me of a wish to mislead you and expose myself by a ridiculous falsehood.

"I enclose you a *baguette*, exactly as I use it, but a larger one (inconvenient to send in a letter) shows the power more fully, as so small a one almost immediately breaks from the twisting of it, near the finger and thumb. I shall only add that many trials since the year 1772 have *convinced me*, that *the fact is certain*, for I myself was slow

to credit it. Should you wish to write again, do me the favour to direct to the Hon^{ble}. ——— at ———.

"I have the honour to be, Sir,

"your obedient humble servant,

——— ——— ———

"April 30, 1805."

"I generally use a baguette about six inches from the vertex to the ends of the twigs where they are cut off."

In consequence of the favour of this respectable and indulgent epistle, as soon as I learned that the lady with her family was arrived in London, I took an early opportunity of waiting upon her ladyship, to pay my respects, and return thanks for the favour done me, at the same time expressing an earnest wish that the lady would further indulge me with a sight of the experiment, performed at any time and place her ladyship might be pleased to appoint. And soon afterwards I had the honour to receive the following note, appointing the meeting for the purpose of showing the experiment.

"Lady ———'s compliments to Doctor Hutton, and proposes to be at Woolwich on Friday the 30th inst. at eleven in the forenoon, if that day and hour will be convenient to Doctor Hutton. Lady ——— will then have the pleasure of showing him the effect of the *Divining Rod*, and requests he will provide some branches of hazel, which she will cut into the proper forms when she arrives.

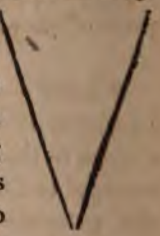
"Doctor Hutton will have the goodness to answer Lady ———, to inform her if he shall be at leisure on Friday to receive her at his house, for the purpose of the experiment.

———

"May 23d."

Accordingly, at the time appointed, the lady, with all

her family, arrived at my house at Woolwich Common; when, after preparing the rods &c, they walked out to the grounds, accompanied by the individuals of my own family and some friends, when Lady ——— showed the experiment several times, in different places, holding the rods, &c, in the manner as described in her ladyship's first letter above given. In the places where *I* had good reason to know that no water was to be found, the rod was always quiescent; but in the other places, where I knew there was water below the surface, the rods turned slowly and regularly, in the manner before described, till the twigs twisted themselves off below her fingers, which were considerably indented by so forcibly holding the rods between them. All the company present stood close round the lady, with all eyes intently fixed on her hands and the rods, to watch if any particular motion might be made by the fingers; but in vain, nothing of the kind was perceived, and all the company could observe no cause or reason why the rods should move in the manner as they were seen to do. After the experiments were ended, every one of the company tried the rods in the same manner as they saw the lady had done, but without the least motion from any of them. And in my family, among ourselves, we have since then several times tried if we could possibly cause the rod to turn, by means of any trick or twisting of the fingers, held in the manner the lady did; but in vain, we had no power to accomplish it. The annexed figure represents the form and position of the rod, about 6 inches in length, cut off just below the joint, or junction of the two twigs.



I am sorry it is not permitted to publish the lady's name. While this edition of the book was in the press, thinking the above particulars might form no improper supplement to what had been said by M. Montucla on this subject, I

addressed a few lines to Lady ——, then in a distant part of the country, to enquire if her name might be mentioned in the account I meant to give; to which I received the following answer in the negative.

"Dear Sir, Oct. 30, 1813.

"Having been from home, I did not receive the favour of your letter till yesterday, therefore take the earliest opportunity of replying to it. As I have ever had a horror of appearing in print, I had rather not have *my name* given with the account you propose of the discovering of springs; therefore, as it will be anonymous, you will judge for yourself how far you may wish to relate the circumstances with which I have acquainted you. They are known to *so many*, that I am of opinion they will obtain credit in a great degree, without a *name* being formally attached to them. I can only repeat, that every experiment I have made confirms the reality of the power, though I cannot account for it.

"Believe me, dear Sir, your faithful servant,

—— ——."

MATHEMATICAL

AND

PHILOSOPHICAL

RECREATIONS.

PART TWELFTH.

Of the Magnet, and its Various Phenomena.

OF all the phenomena exhibited to us by nature, magnetism, or the properties of the loadstone, and electricity, may with justice be considered as the most extraordinary, as the causes of the effects produced by them have occasioned the greatest difficulties to philosophers; for it must be confessed that, notwithstanding all their attempts to explain them, we are as yet acquainted only with facts. They have been able indeed to apply certain hypotheses to some of these phenomena; but if we examine these hypotheses with an unprejudiced eye, and without suffering ourselves to be the dupes of illusion, we cannot help acknowledging that they have little solidity, and that they are subject to difficulties which cannot be removed, as long as we make it a rule to reason only from the known properties of matter, and the laws of motion. Posterity perhaps will be more successful; and, assisted by time and

accumulated experiments, will see more clearly into those matters; or perhaps they may for ever remain an impenetrable secret to the human mind.

In this part of our work we shall confine ourselves, in speaking of the magnet, to its properties, and the philosophical amusements which may be performed by their means. Electricity will furnish matter for the succeeding part.

ARTICLE I.

Of the Nature of the Magnet.

The magnet is a metallic stone, commonly of a greyish or blackish colour, compact and very heavy, and is usually found in iron mines. It affects no particular form; exhibits no external marks, to distinguish it from the meanest productions of the bowels of the earth. But its property of attracting or repelling iron, and of directing itself to the north, when at full liberty to move, gives it a title to be classed among the most singular objects of nature.

This stone, properly speaking, is merely an iron ore, but of that kind which is called poor; because it contains only a small quantity of metal. Modern metallurgists indeed have been able to extract iron from it; but, besides that it is difficult to be fused, it is so unproductive, that it would not pay for the expence of working it.

But it may here be asked, why is not every kind of iron ore magnetic? This is a question to which, in our opinion, no answer has ever been given. Its magnetic virtue arises, no doubt, from a peculiar combination of iron with the heterogenous particles to which it is united; and perhaps it contains some principle which does not enter into the other ores of that metal: but it must be allowed that this does not solve the difficulty. However, it is not impossible that chemical analysis may some day discover in what this combination consists; and it is not improbable, that

our profound ignorance respecting the physical causes of the action of the magnet, may arise from chemists having hitherto neglected to make this production of nature a subject of their researches.

Formerly, the loadstone was exceedingly rare. The name *magnes*, by which it was known both among the Greeks and the Romans, seems to have originated in Magnesia, a province of Macedonia, where it was found in great abundance, or which furnished the first magnets known. But the loadstone has been since found in almost every region of the earth, and particularly in iron mines. The island of Elba, so celebrated for its mines of that metal, worked from the earliest ages, is said to furnish the largest and best magnets.

ARTICLE II.

Of the Principal Properties of the Magnet.

The ancients were acquainted with no other property of the magnet, than that which it has of attracting iron; but the moderns have discovered several others; such as its communication, its direction, declination and inclination, to which we may add its annual and daily variation.

§ I.

Of the attraction which prevails between the magnet and iron, or between one magnet and another.

EXPERIMENT I.

Which proves the attractive power of the magnet over iron.

Every person is acquainted with the attractive force which the magnet has upon iron. If filings of that metal be presented to a magnet, and even at some distance, you will see the filings dart themselves towards the stone, and adhere to it. The case will be the same with any small and light bit of iron, such as a needle; this will approach

accumulated experiments, will see more clearly
matters; or perhaps they may for ever rem
penetrable secret to the human mind.

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EXPERIMENT II.

of a Magnet.

iron filings, and then drawn
covered all over with them; but it

will be observed that there are two places, diametrically opposite to each other, which are the poles, where the filings are closer, and where the small oblong fragments stand as it were upright, while in other parts they lie flat.

By this experiment we are enabled to find the poles of the magnet. Every magnet indeed has two poles, or two opposite points, which, as will be seen hereafter, possess different and peculiar properties. One of these points is called the *north* pole, and the other the *south*; because, if the magnet be freely suspended, the former will turn of itself to the north, and consequently the other will be directed to the south. When it is intended to perform experiments with a magnet, these two points must be first determined.

EXPERIMENT III.

Properties of the Poles of the Magnet, in regard to each other.

Provide a magnet; and having determined its two poles, make it float on the water by placing it on a piece of cork of a proper size; if you then present to the north pole of this stone the same pole of another, the former will be repelled, instead of attracted; but if you present to its north pole, the south pole of another, it will be attracted.

In like manner, if to the south pole of the former you present the south pole of the latter, the first will recede; but if you present to this south pole, the north pole of the second, it will approach.

The poles then of the same name, repel; and those of a different name, attract each other.

EXPERIMENT IV.

To produce New Poles in a Magnet.

If a magnet be cut in a direction perpendicular to the

axis passing through its two poles A and B, pl. 6 fig. 37, there will be formed by the section two new poles, such as F and E; so that if A be the south pole of the whole stone, E will be a north pole, and F a south pole. By this bisection, therefore, the north side of the stone will acquire a south pole, and the south side a north pole.

REMARKS.—A magnet, however good it may be, unless it be very large, will scarcely support a few pounds of iron; and, in general, the weight which a magnet can carry is always very much below its own weight. But means have been found out, by employing what is called arming, to make it produce a much more considerable effect. We shall therefore describe the method of arming a magnet.

First give the magnet a figure nearly regular, and square its sides where the two poles are situated, so that these two sides may form two parallel planes. Then make, of soft iron, for steel is not so good, two pieces, such as that seen fig. 38, the long and flat side of which may be of the same length and breadth as the faces of the magnet where the poles are situated. The proper thickness however of this side, as well as the projection of the foot, and its thickness, can be found only by repeated trials. These two pieces must embrace the magnet on the two faces where the poles are situated, the feet passing below as if to support it; and they must be fastened in that situation by transverse bands of copper, surrounding the magnet, and compressing the long branches of these pieces against the faces of the poles.

Then provide a piece of soft iron, of the form seen fig. 39, a little longer than the distance between the bands of iron applied to the poles of the magnet, and in thickness somewhat more than the flat faces of the lower part of the feet of the arming. In regard to the height, it must be regulated by what may appear most convenient. Pierce

a hole in it towards the middle, to receive a hook for the purpose of suspending from it the weight to be supported by the magnet. Fig. 40 represents an armed magnet, which will be sufficient to give an idea of the whole arrangement, without any further explanation.

A magnet armed in this manner will support a much greater weight than one not armed. A stone, for example, of 2 or 3 ounces, will by these means support 50 or 60 ounces of iron; that is, 20 or 30 times its own weight.

Lemery says he saw a magnet, of the size of a moderate apple, which supported 22 pounds. Some have been seen, of 11 ounces, which could support 28 pounds. The sum of 5000 livres (above 200*l.* sterling) was asked for it. M. de Condamine, of the Royal Academy of Sciences, possessed one, given to him by Maupertuis, which was capable, we believe, of supporting a weight much greater than any other magnet known. We do not remember its dimensions, or its weight, neither of which was very considerable; but, if we recollect right, he used to say that it could support 60 pounds.

II. Researches have been made to discover, whether there be any other bodies, besides iron, susceptible of being attracted by the magnet: from which it appears indeed that there are not. Yet Muschenbroek says, that the magnet seemed to exercise an action on a stone which he calls *Lough-neagh.* We are not acquainted with this stone. But it is probably some kind of iron ore, in which that metal is a very little mineralised.

In his *Cours de Physique Experimentale,* Chap. 7, he gives an account of some trials, made on a great many different kinds of matter, to ascertain whether they were susceptible of being attracted by the magnet. He found that this stone, without any preparation, attracted the whole or

a great many of the particles in different kinds of sand and earth, which he enumerates. Several others presented no particles susceptible of attraction by the magnet, until they had been exposed to the action of fire, by bringing them to a red heat, and burning them with soap or charcoal, or grease: after which, says he, they were attracted by the magnet, with almost as much force as iron filings; such, adds he, are the earth of which bricks are made, and which becomes red when burnt; also different kinds of bole and coloured sand. Others, when burnt in this manner, presented only a few particles, susceptible of being attracted by the magnet: of these he gives a long enumeration, which we shall not here repeat.

This will not appear surprizing, if we compare the two following facts: the first is, that the magnet never attracts iron, but when in its metallic state; and that it has no action on this metal when calcined, or reduced to the state of an oxyde: the second is, that iron is universally diffused throughout nature, and in almost all bodies, more or less distant from its metallic state, as will be seen hereafter. Bodies which contain it in its metallic state, are all, or in part susceptible of being attracted by the magnet, without any preparation: but in others, it is not susceptible of attraction till it has been burnt with fat matters, which restore it to its metallic state. Such is the only cause of the phenomenon which seems to have embarrassed Muschenbroek. It would have occasioned no difficulty, had he been as well acquainted with chemistry, as with the other branches of philosophy.

An English navigator says, he observed that grease, which happened to fall on the glass of a mariner's compass, disturbed the magnetic needle, and that brass produced the same effect. If this observation be correct, we must conclude, that the tallow and brass accidentally con-

tained some ferruginous particles; for in our opinion it may be considered as certain, that iron alone, in its metallic state, has the power of acting on the magnet, and is susceptible of being attracted by it.

EXPERIMENT V.

The Direction of the Magnetic Current.

Place an unarmed magnet on a piece of pasteboard, and throw iron filings around it: if you then tap gently on the pasteboard, you will see all the filings arrange themselves around the magnet, in curved lines, which, approaching each other like the meridians in a map of the world, meet at its two poles.

This experiment favours the opinion of those who think that the magnetic phenomena depend on a fluid, which issues from one of the poles of the stone, and enters at the other, after having circulated around it.

EXPERIMENT VI.

Which proves that the magnet and iron have a Mutual Action on each other.

Place two magnets, or a magnet and a piece of iron, on two bits of cork, made to float in a bason of water. Having then turned the north pole of the one towards the south pole of the other, provided two magnets are employed, if the two pieces of cork be left to themselves, you will see them proceed towards each other; the weaker moving faster than the other. The case will be the same, if a bit of iron be presented to the north pole of the magnet. This attraction then is reciprocal; and it may be said that the iron attracts the magnet, as much as the magnet does the iron. This indeed must necessarily be the case, since there is no action without re-action, and as the latter is always equal to the former.

Remark.—Muschenbroek endeavoured to determine in

what ratio the action of the magnet decreases, according to the distance; and he thought he observed, that its attractive force decreased in the quadruple ratio, or as the 4th powers of the distances. Thus, if at a line distance, a particle of iron is attracted with a force equal to 1; at 2 lines distance, that force will be 16 times less; at 3 lines, 81 times less; at 4 lines, 256 times less; and so of the rest. This action perhaps decreases still more rapidly; for in a ship of war laden with large iron cannon, it is not observed that they have a sensible action on the compass. In our opinion however, it would be prudent to remove them to as great a distance as possible.

§ II.

Of the Communication of the Magnetic Property.

Magnetism, or the property of attracting iron, and of turning towards a certain point of the heavens, is not so peculiar to the magnet, as to be incapable of being communicated; but no bodies have yet been found susceptible of this communication, except iron and steel. About a century ago it was believed that contact alone, or the continued presence of a magnet, could produce this effect; but a method has since been discovered, to render a piece of iron magnetic, without the magnet; and these artificial magnets are even susceptible of acquiring a strength rarely found in natural magnets. We shall give an account, in the following experiments, of the different methods of communicating the magnetic virtue.

EXPERIMENT VII.

Method of Magnetising.

Provide a magnet, either armed or unarmed, and make one of the feet of the armour, or one of the poles, to pass over a plate of tempered steel, such as the blade of a knife, but proceeding always in the same direction, from the

middle, for example, towards the point. After performing this operation a certain number of times, the plate of iron will be found to be magnetised, and, like the magnet itself, it will attract iron, if placed within the sphere of its attraction.

The case will be the same, if a long slender bit of steel be left a long time attached to a magnet: the steel, by remaining in that situation, will acquire the magnetic property; it will have poles like the magnet, so that the north pole will be at the end which was near the south pole of the stone, and the end which touched the north pole will become the south pole.

EXPERIMENT VIII.

Method of making an Artificial Magnet with bars of steel.

We shall here show the method of making, with bars of steel, an artificial magnet, much stronger than a natural one. For this purpose, provide 12 bars of tempered steel, about 6 inches in length, 6 lines in breadth, and 2 in thickness. Care must be taken, before they are tempered, to make a mark with a punch, or in any other manner, at one of their extremities. Arrange six of these bars in a straight line, but so as to be in contact, and that the marked ends shall be directed towards the north; take an armed magnet, and place it on one of these bars, with its north pole towards the marked end, and the south pole towards the other end; then move the stone over the whole line, beginning at the unmarked end of the first, and repeat this operation three or four times.

When this is done, remove the two bars in the middle, and substitute them for those at the two extremities, which must be placed in the middle; then move the stone in the same direction over the four bars in the middle only; for it is needless to comprehend those at the extremities; and

invert the whole line, that is to say turn up the face which was turned downwards, and magnetise the bars again in the same manner, taking care to transpose the bars at the extremities into the place of the middle ones.

By these means, you will have six magnetised bars, which must be formed into two parcels, each containing three. In these parcels, the northern extremities must be towards the same side, but when the one parcel is placed upon the other, care must be taken that the northern extremities of the bars of the one may rest upon the south extremities of those of the other. These two parcels must touch at their upper part, and be separated on the other side; this separation may be effected by means of a bit of wood placed between them.

Then place the six bars which were not touched in the same manner as the preceding six, and magnetise them as above described, by means of the double parcel of the former; that is to say, by drawing the two extremities north and south of this double parcel over the new series of bars: you will thus have six bars much more strongly magnetised than the former. Then make a line of the six former, and magnetise them in the same manner with the double parcel formed of the second, according to the same method, and you will obtain bars of steel capable of supporting 16 times their weight, and more.

This is the process of Mr. Michell, fellow of the Royal Society of London. Mr. Canton, a celebrated observer of the phenomena of the magnet, has given a method of effecting the same thing, and M. Duhamel, of the Academy of Sciences, another, which may be seen in a small treatise on Artificial Magnets, printed in 1775. We shall say nothing further on this subject, but only remark, that by these processes, the weakest commencement of magnetism is sufficient to produce magnetic bars of the great-

est force. It is not even necessary to have a magnet; for, in the following experiment, we shall describe various methods of communicating magnetism without one.

EXPERIMENT IX.

To produce the magnetic virtue in a bar of iron, without the use of a magnet.

To propose communicating the magnetic virtue without the use of a magnet is, no doubt, a sort of paradox. This however has been effected in consequence of some theoretic considerations in regard to the nature of the magnet, and the manner in which the magnetic fluid acts on iron. A magnet therefore is not necessary to produce the commencement of magnetism, which may be afterwards increased to a considerable degree by the process before explained.

Canton, Mitchell, and Antheaume, have given different methods for magnetising without a magnet. According to Mr. Canton, take a poker, and having placed it between your knees, in a vertical direction, with the point downwards, affix lengthwise to its upper part, by means of a silk thread, a small plate of soft tempered steel; then holding this apparatus in the left hand by the silk thread, take a pair of tongs, and, holding them almost vertically, rub the small bar from the bottom upwards, about a dozen of times, with the lower end of them: by these means you will communicate to it a magnetic force, capable of making it support a small key.

Mr. Mitchell employed another method. Place, says he, a small bar of steel in a straight line between two iron bars, in the direction of the magnetic meridian, and in such a manner, that they shall be somewhat inclined towards the north: then take a third bar, and holding it almost vertically, but with the upper extremity a little

inclined towards the south, glide the lower extremity of this bar along the three other bars situated in a straight line, taking care to make it move from north to south: the result will be a commencement of the magnetic virtue in the bar of steel.

M. Antheaume's method is as follows: First fix a board in the direction of the magnetic current; that is, inclined at an angle of about 70 degrees towards the horizon, so that its horizontal projection shall make one of about 20 degrees. Then place in a line, on that board, two square bars of iron, four or five feet in length, or even more, and 15 lines in thickness: they must be filed square at the extremities which are opposite to each other. Each of these extremities must be furnished with a small square of iron plate, two lines in thickness, so as to project beyond the upper face of the bar the height of a line, and filed square on that side, to form above the bar a kind of knee. The three other sides of this square of iron plate must slightly touch the corresponding faces, and be cut into a bevel. In the last place, a small bit of wood must be placed between the arming of the extremities of these two bars.

When every thing is thus arranged, glide the bar of steel to be magnetised, over the two knees above described, by making it move gently from one of its ends to the other, as an iron bar is magnetised, on the two knees of its arming. M. Antheaume says, he was surprised to find that he could magnetise by this method, not only small bars of steel, as Messrs. Canton and Michell did, but bars of a foot in length, and several lines in thickness.

The same philosopher says, he observed that steel *de carme*, or *à la rose*, and English steel, are the fittest for this purpose; that the operation succeeds best with the first kind, when tempered hard in the usual manner, and that English steel requires to be tempered in bundles;

lastly, that if steel tempered and annealed be employed, the temper is a matter of indifference.

Remark.—Even the rubbing of one piece of iron over another is not necessary to produce the magnetic virtue. It has been observed that a bar of iron, kept for a long time in the direction of the meridian, or in a situation nearly approaching to it, acquires the magnetic virtue. The steeple of Notre Dame de Chartres having been considerably damaged by a great storm in 1690, some bars of iron taken from it were found to be magnetic. But, what is still more remarkable, pieces of these bars, which were almost destroyed by rust, formed excellent magnets. The Abbé de Vallemont wrote at that time an account of them, which was published in 1692.

Gilbert, an English physician and philosopher, who wrote a treatise on the magnet, in 1640, had then observed that the small bars of an iron window frame, placed north and south, which had remained many years in the same position, were become magnetic. He relates also*, that the wind having bent an iron bar which supported an ornament on the church of St. Augustine, at Rimini, when the monks belonging to it were desirous, ten years after, to straighten this bar, they were much surprised to find that it possessed all the properties of a good magnet. Muschenbroek speaks of a similar circumstance, in regard to some pieces of iron taken from the tower of Delft. We read also in the Memoirs of the Academy of Sciences, for the year 1731, that there was at Marseilles a bell which moved on an iron axis, standing in an east and west direction, and resting with its two ends on stone; that the rust of these ends mixing with the dust rubbed from the stone, and with the oil used to facilitate its motion, formed together a hard and heavy mass, which when detached was

* Book III. chap. 13.

found to possess all the properties of the magnet. It is believed that this bell had existed in that situation 400 years.

Gilbert observes also, that if a bar of iron, placed north and south, be brought to a red heat in a forge, and be then beat on the anvil in the same position, it will acquire the magnetic virtue; and that if this virtue be not immediately sensible, it will become so by repeating the operation. But it is to be observed, that for this purpose the length of the iron must be 100 or 150 times its diameter. The case is the same with a bar of iron, if it be heated, and then cooled in the direction of the meridian.

The following conjecture of this philosopher, however, has not been verified. He says that if a spherical form be given to a magnet, and if its two poles be at the extremities of a diameter; this spherical magnet, when placed in complete equilibrium, and suspended on its poles, will turn round its axis in 24 hours: for as the earth, adds he, is but a large magnet, it must have a similar motion. This would have been a pretty strong proof of the motion of the earth, at least around its axis; but M. Petit, an industrious philosopher of the last century, having taken the trouble to make the experiment proposed by Gilbert, the small magnetic globe remained perfectly motionless. This does not however prevent the motion of the earth from being certain, and it may even be considered as a large magnet, though Father Grandamy concluded, from the failure of Gilbert's experiment, that the earth was motionless.

ARTICLE III.

Of the Direction of the magnet; and of its Declination and Variation.

EXPERIMENT X.

To find the Direction of the magnet.

Having found the poles of a magnet, if you place it on a small bit of cork, and make the cork to float on water, it will always place itself in one direction.

The case will be the same with a magnetic needle made to float on water by the same means, or suspended on a fine pivot, so as to be at full liberty to move: it will always assume the same direction.

To make a needle place itself north and south, it is not even necessary that it should be magnetised. When exceedingly light, and perfectly free to move, it spontaneously assumes that direction.

If a very slender common needle be made to float on the surface of water in a state of perfect rest, at the end of some hours it will be found in the same direction as that suddenly assumed by the magnetic needle.

The direction, according to which a needle, whether magnetised or not, arranges itself, is called the *magnetic meridian*, and must be carefully distinguished from the terrestrial or true meridian; for we shall soon show that, in general, they form an angle with each other. Philosophers agree, almost unanimously, in thinking that this property of the magnet is produced by a current of a particular fluid, surrounding the earth, and which, passing through the magnet lengthwise, or from one pole to the other, makes it assume its proper direction.

What is very singular is, that not only the magnetic meridian, in almost all places of the earth, is different from the terrestrial meridian; declining sometimes to the east

and sometimes to the west; but that this declination varies annually, as is proved by the following experiments.

EXPERIMENT XI.

If a magnetic needle be suspended on a pivot, in the direction of a meridian line, traced out with great care, and at a distance from any iron, you will generally find that the direction it takes will form an angle with the meridian. In 1770, for example, it was at Paris 19° 55′ west.

If the experiment be repeated some years after, it will be found that this angle is not the same; but that it has increased or decreased. In 1750, for example, it was at Paris 17° 15′ west; in 1760 it was observed to be 18° 45′; in 1770 19° 55′, or even 20 degrees and some minutes. And, at London, in 1800, it was about 22° 30′; while it is now, in 1813, about 24° 17′.

REMARK.—In the greater part of our continent, as well as in all North America, except that part of it which is nearest the Gulph of Mexico, the declination is at present west, and goes on continually increasing. In all North America and all the Gulph of Mexico, as well as part of the Pacific Ocean, between the tropics, and on the southern coast, the declination is east, and goes on continually decreasing.

The celebrated Dr. Halley, having taken the trouble to collect a prodigious number of observations, made by different navigators, published in 1700 a very curious chart, in which he connected, by lines, all those places of the earth where the declination of the magnetic needle was the same. It is there seen, for example, that the line on which the magnetic needle in 1700 had no declination, divided nearly the southern part of the Atlantic Ocean, and cut the equator towards the first degree of longitude, or at its intersection with the first meridian; it thence

proceeded in a curved line to New England, and, traversing New Mexico and California, stretched to the north of the Pacific Ocean. In all probability it reached Asia, then passed to the north of Tartary, and proceeding through China, traversed New Holland. On the south and west of this line, the declination was east; on the north and east it was west.

By other observations, made at a later period, it appeared that this line was displaced; and that it had in some manner a motion towards the south-west, changing a little its form. According to those observations collected by Messrs. Mountain and Dodson, of the Royal Society, it traversed, in 1744, the middle of the Atlantic Ocean, nearly intersected the equator towards the 12th degree of longitude, to the east of the first meridian; proceeded thence to the middle of Florida, and passing nearly along the coast of Louisiana, it traversed Old Mexico, from which it extended to the point of California, then to the north of the Pacific Ocean, and intersected the first meridian towards the 44th degree of north latitude; from which it turned southwards, and traversed Japan, the largest of the Philippines, the kingdoms of Pegu and Arracan, and formed a point on the east near the island of Ceylon. It then returned, and traversing the Moluccas, proceeded in a curved line towards the south pole, leaving New Holland on the west. Such was the position of this line in 1744; and thence we may determine nearly its present position.

Dr. Halley's chart exhibited also the line which joined all the points where the declination was 5° to the east or the west; those where it was 10°, 15°, &c. It is observed, at present, that they have all had a motion nearly similar to that of the line without declination.

Dr. Halley's object, in this painful labour, was not mere curiosity; he intended these charts to be employed in de-

termining the longitude at sea. If an accurate chart of these lines of declination were indeed constructed, it is evident that, by observing the latitude and the real declination of the compass, the precise point of the earth, where the observation was made, would be determined. Let us suppose, for example, that the declination has been observed in the Atlantic Ocean, to be 7°½ west, the latitude being 32 north. It is evident, in this case, that the ship's place will be the point where the parallel of 32° north, intersects the line of 7°½ declination. Nothing then would remain, but to improve the means of determining the declination with great exactness, which is a thing not impossible.

It is to be regretted that we have no old observations of the declination of the magnetic needle. The reason of this no doubt is, that the declination was not properly ascertained by philosophers, till towards the end of the 16th century. It is seen however, by the observations which have been made, that at Paris, at London, and in great part of Germany, the declination formerly was east; for in 1580 it was found at Paris to be 11° 30′ east. After that time it decreased till 1666, when it vanished entirely; it then became west, increasing continually in that direction; for in 1670 it was observed to be 1° 30′, in 1680 to be 2° 40′, in 1701 to be 8° 25′, in 1770 it was observed to be within a few minutes of 20°. The Royal Society of London recorded their annual observations of the magnetic needle for many years; and it is a great pity that they afterwards discontinued such useful observations; but have lately resumed them again.

But what is the cause of the magnetic declination? on this subject we shall offer the following conjectures. Messrs. de la Hire, senior and junior, made a curious experiment, which may serve to throw some light on the cause of this phenomenon. They took a very large mag-

net, and having given it a globular form as nearly as possible, they sought for its poles, which were found exactly at the extremities of a diameter; and then they traced out on it its equator, and twelve meridians. On this magnetic globe, which was about a foot in diameter, and which weighed nearly a hundred pounds, they applied a magnetic needle, and observed that there were places where it declined towards the west, and others where it had no declination, and which formed one or two continued lines on the surface, as Dr. Halley had determined on the surface of the earth, though of a form absolutely different.

It is more probable, says the historian of the Academy, that the cause of the declination observed on the magnetic globe was merely the inequality of its contexture, and of the magnetic force of its different parts. There is reason also to conjecture that the earth, being a large magnet, or at least a globe containing in its bosom large magnetic masses, it is the unequal distribution of these masses that occasions on its surface the variety of the direction of the magnetic needle. But there is this difference, that in the bowels of the earth new masses are continually generated; whereas the magnet of Messrs. de la Hire experienced nothing of the kind. Hence it happens that, on the surface of the earth, the direction of the magnet is variable; while on the surface of the magnetic globe it was necessary that it should be constant.

It must however be allowed, that in this explanation, it is difficult to assign a reason, why, for two centuries, at least, the line without declination has been seen to move constantly from east to west. Effects arising from causes so variable as the destruction and generation of masses in the bosom of the earth ought to experience greater irregularities, and the progress of the magnetic needle ought to be sometimes east and sometimes west.

Dr. Halley proposed a physical hypothesis, to account

for the variety in the magnetic declination. He supposed two fixed magnetic poles, and two moveable, in certain positions. But this hypothesis has been simplified by Albert Euler, in a curious memoir, which may be seen in the Transactions of the Academy of Berlin for the year 1757. Euler supposes only two magnetic poles, one at 14° 53′ from the north pole of the earth, and the other 29 23′ from the south pole. The meridian in which the former is situated passes through the 258th degree of longitude, and that of the second through the 303d. He then assumes, as a principle, that the magnetic needle always ranges itself in the plane passing through the two magnetic poles and the place of observation; and he determines, by calculation, the inclination of that plane to the meridian, in the different places of the earth. By means of these data, calculation gives, with great exactness, the quantity of the declination observed of late years, and the position of the lines of declination, as they were found by Messrs. Mountain and Dodson, for 1774, at least in the Atlantic Ocean; for Albert Euler is obliged to consider as false the position given to the line of declination, in the north part of the Pacific Ocean, by those members of the Royal Society, and what he says on this subject is highly probable.

It may be easily conceived, that by making these poles to vary, the lines of declination will vary also, and that according as they approach or recede from each other, they may change their form, as has indeed been observed.

Mr. Canton, a member of the Royal Society of London, discovered some years ago a new motion of the magnetic needle, which is founded on the following experiment.

EXPERIMENT XII.

Diurnal Variation of the magnet.

Provide a pretty large magnetic needle, 12 or 15 inches

in length, and nicely suspended. It must be surrounded by a circle, the centre of which is the point of suspension, divided into degrees, and half degrees, or quarters, at least in that part of its circumference which is opposite to the point of the needle. The whole apparatus must be covered in such a manner, as to prevent it from being subject to any impression from the air.

f this needle be observed at different hours of the day, it will be found that it is scarcely ever at rest. According to Mr. Canton, the declination will be greatest in the morning, and least in the evening: about noon it will be a mean between these two extremes. He assigns also a very probable reason, which is as follows:

It is a fact proved by experience, that a magnet, when heated, loses a little of its force. But as the eastern parts of the earth have noon when the sun rises to us, it is at that time, or nearly so, that they are most heated. The magnetic needle, the direction of which is, in all probability, an effect compounded of the attraction of all the magnetic parts of the earth, will at sun rise be a little less impelled towards the east, than if the sun were not on that side; consequently it will yield to the action of the western parts, and will turn a little more towards that side. Mr. Canton even renders this explanation sensible, by means of two magnets, each of which is heated alternately.

But, whatever truth there may be in this explanation, the phenomenon is now well known; and meteorologists do not fail to observe, at different times, the declination of the magnetic needle, which often varies between morning and night, 20′ and more*.

* See *Traité de Météorologie du P. Cotte.*

§ III.

Of the Inclination or Dip of the magnetic needle.

EXPERIMENT XIII.

To observe the Inclination of the magnet.

If the needle of a compass, not yet magnetised, be placed in perfect equilibrium on its pivot, so as to remain parallel to the horizon; and then be touched with a magnet, it will lose this equilibrium, and will dip its northern extremity below the horizon.

This experiment is well known to those who construct compasses; for after the needle is magnetised, they are obliged to file the heavier end till it be in equilibrium with the other. The same effect might be produced by loading the other end with a small weight, and it would even be of advantage if this weight were moveable; for as the inclination is variable, different forces are required to form an equilibrium to the effort made by the needle to dip. It is therefore necessary to add a small weight to one of the ends of the needle, according to the different positions of the ship, in order that it may remain perfectly horizontal.

EXPERIMENT XIV.

To observe the Inclination of the magnetic needle.

Provide a magnetic needle, made of very straight steel wire, terminating in a point at each extremity. The middle of it must be flattened, and formed into a small circle, having its centre in a line with the two points of the needle. A piece of very fine steel wire passing through this circle, in a perpendicular direction, must serve it as a pivot; so that when suspended horizontally in two holes, made in two vertical plates of brass, it may be indifferent to every position, and remain in equilibrium

in any situation whatever. These two plates must be affixed to the edge of a brass band, bent into a circular form, and of a diameter somewhat greater than the length of the needle, the pivots of which will be in the centre. This brass circle must be suspended in a ring, and one of its diameters must be placed in a vertical direction. Divide the inside of it into degrees, and quarters of a degree, if possible, but in such a manner that the division beginning with zero, at the extremities of the horizontal diameter, may end with 90 degrees at the extremities of the vertical diameter. The position of this diameter may be ascertained by means of a wire and plummet, suspended from its upper extremity, and which must pass through the lower extremity, that it may be in its true position.

Provide also a wooden stand in the form of an oblong parallelopipedon, in the upper part of which let there be a circular hollow proper for lodging the instrument in the direction of its length. In the last place, there must be a small wedge, for the purpose of being placed under this stand, till the plane of the instrument, or that passed over by the needle in its motion, shall be exactly vertical.

When the needle has been magnetised, apply to the two sides of the instrument, in grooves made for that purpose, two circular pieces of glass, to preserve the needle and its pivots from the contact of the exterior air, and from moisture, which is hurtful to magnetism.

By the description of this instrument, it may be readily seen, that it must be disposed in a vertical situation, either by suspending it or placing it on its supporter, which may be easily done by means of the wire and plummet.

The plane of the instrument also, or that passed over by the needle, must be in the plane of the magnetic meridian. For this purpose, lay the instrument flat on a horizontal table; the needle, when it stops, will indicate the magnetic meridian; then draw on the table a line in

that direction, and make the long side of the supporter coincide with it. By means of the small wedge and the plumb line, it may then be adjusted in the proper position. The needle, after very long vibrations, will at length stop, and indicate by its point the number of degrees it is distant from the plane of the horizon, which will give the inclination or dip desired.

By these means it is found that the inclination at Paris is at present (viz, 1790) 72 degrees, and at London, in 1808, it was 70° 1′.

REMARKS—I. Though the construction of such an instrument does not seem difficult, it is shown by experience that it requires a peculiar kind of skill and dexterity, which few possess. Unless the instrument indeed be perfect, the magnetic needle does not recover its position when displaced, or when the instrument is turned in a contrary direction; that is, in such a manner that the plane which looked towards the east may look towards the west.

II. The inclination of the magnetic needle is no less variable than its declination. It is observed that it is different in different parts of the earth; but it is erroneous to suppose, as some philosophers in the last century did, that it has any relation to the latitude. It is observed, for example, that it is at Paris at present 72° 25′ North.

At Lima, about 18° South.

At Quito, about 15° S.

At Buenos-Ayres, about 60°½ S.

At the Isle of France, 52°¾ North.

This is sufficient to destroy the idea that it has the least relation to the latitude.

As observations of the inclination are considered to be of no utility in navigation, it needs excite no astonishment that we have so few. Besides, it is much more difficult at sea to observe the inclination, than the declination, on ac-

count of the rolling of the ship. Father Feuillée however made a considerable number of them, during his voyages in Europe and America; but, according to all appearance, they are only within a few degrees of the truth. It is nevertheless to be wished that these observations were more numerous; for though, on the first view, they do not seem of great utility, they may become so hereafter. Let us not cease to accumulate facts, though in appearance useless. Some unexpected light often arises from an observation long considered to be frivolous, and unimportant.

III. We may remark also, that the motion of the magnetic needle experiences very singular variations on the approach, or by the effect of, igneous metors. A needle has been deprived of its magnetic property by thunder, or even magnetised in a contrary direction. The Aurora borealis seems also to have a very sensible action on the magnetic needle; but for farther information on this subject, we must refer to Father Cotte's *Traité de Météorologie.*

ARTICLE IV.

Of certain means proposed for freeing the magnetic needle from its declination, or for making compasses without declination.

It would be so great an advantage to have compasses which should point exactly to the north, that the attempts made to devise combinations to destroy the declination of the needle need excite no surprise; but unfortunately these attempts have hitherto been fruitless, and in our opinion will always be so. They however deserve to be known, were it only to guard our readers against the illusions of those who imagine that they have solved this problem.

One of these inventions is described by Muschenbroek. It consists in combining, for a determinate place, two needles of equal force, in such a manner, that the one may

decline on the one side, and the other on the other side, from the magnetic meridian by a quantity equal to the declination. Thus, one of them will decline double and the other will be exactly in the meridian. Let us suppose, for example, that the declination is 20 degrees to the west, as it was at Paris in 1770. If two magnetic needles of the same force be suspended on the same pivot, forming together an angle of 40 degrees; it is evident that neither of them being able to place itself in the magnetic meridian, they will equally decline from it: thus the one will decline 20 degrees to the west of that meridian, or 40 degrees from that of the earth; consequently, the other needle will necessarily be in the meridian, and will have no declination.

It is astonishing that any one should imagine that a combination of magnetic needles, capable of making one of them coincide with the terrestrial meridian, could be obtained in this manner. It may be readily seen, that these two needles, if of equal force, will always arrange themselves in such a manner, that the magnetic meridian will divide into two equal parts the angle comprehended between them. Thus, if we suppose that the magnetic meridian, instead of declining 20 degrees from the terrestrial meridian, declines only 10 degrees to the west, one of the needles will be carried 20 degrees more to the west; consequently will have 30 degrees of declination. At the same time therefore the other needle will be carried 10 degrees from the meridian towards the east.

The last translator of Pliny has given a method, nearly similar, for annihilating the declination, and which differs in nothing from that of Muschenbroek, except that one of the needles must be larger than the other. But Muschenbroek had before proposed and analysed this combination of two unequal needles, and it appeared to him as unlikely to succeed as the other. It is opposed indeed

by the same, or by similar reasons, and nothing can rest on slighter grounds, than the physical theory by which the author alluded to appears to have been guided; for he seems to think, that the cause of the declination, is a sort of weakness in the needle, which does not permit it to reach the north. This is an idea not only void of foundation, but even incompatible with the most probable theory of the magnetic motion: for as the magnetic needle, which during the first half of the 17th century declined to the east, afterwards approached the north, and passed it, to proceed to the west, it would be necessary to say that it was sick; since it was cured about 1660, and that it afterwards got diseased in a contrary direction. We cannot therefore sufficiently wonder at the precipitation of some journalists and some authors, who hastened to announce, with the greatest eulogiums, this pretended discovery, as likely to change the face of navigation. Unfortunately, nothing could be more chimerical; and a better acquaintance with the magnetic phenomena would have preserved both from this error.

We have seen formerly at Paris a Genoese pilot, named Mandillo, who pretended to have found another combination of magnetic needles, proper for correcting the declination. He placed two needles of equal force above each other, but in such a manner that each of them had full liberty to move; he then brought them together, for Paris we shall suppose, so that their deviation was double the inclination observed; for in this position they would each diverge by the effect of the repulsion of their poles or points of the same denomination, and so much the more as they were brought nearer to each other. By these means, one of the needles, as in the preceding process, was carried to the meridian. But the sieur Mandillo pretended that this would every where be the case, which is evidently false; for the deviation of the two

needles being the effect of the repulsion of the two poles of the same name, this repulsion, and consequently the deviation, will be the same, whatever be the angle of the magnetic meridian with the terrestrial meridian; otherwise we must suppose that this repulsion decreases at the same time as the declination, which is impossible. This objection we mentioned to Mandillo; but to no purpose. A man who imagines he has found the means of correcting the declination of the magnetic needle, or has discovered the solution of the problem of the longitude, is as obstinate in his opinions, as he who thinks he has found the quadrature of the circle.

We shall here mention an idea of M. de la Hire on this subject. It was founded on a belief of his having discovered, that the poles of a natural magnet had changed their place, as the magnetic poles of the earth had done at the same time. He thence conceived the idea of magnetising steel rings, presuming that their poles would change in the same manner. But it may be readily seen that in this case, the line marked originally north and south on the ring would remain motionless, and would always indicate the real north. This principle however has been found to be false; and even if true, the consequence deduced from it by M. de la Hire did not necessarily follow.

ARTICLE V.

Of certain Tricks which may be performed by means of the magnet.

For some years past, the properties of the magnet have been employed to perform several tricks, which excited a considerable degree of astonishment in those who first beheld them. No means indeed more secret, and at the same time more proper for action, could be employed than magnetism; since its influence is stopped by no body

with which we are acquainted, except iron. This idea was first conceived by the celebrated Comus, who varied in a singular manner the different tricks performed by this agent; so that all Paris flocked with the utmost eagerness to the places where they were exhibited. He was admired by the ignorant, who considered him as a sorcerer, while the learned endeavoured to discover the artifice, which however was a profound secret, as long as no one suspected magnetism to be the principal cause of it.

We shall here endeavour to give an idea of some of these tricks, as they will form a fund of rational amusement to those who know how to perform them.

§. I.

Construction of a Magic Telescope.

Those who exhibit these tricks often employ a pretended magic telescope, by means of which one can see, it is said, through opake bodies. It is nothing else than an instrument in the form of a telescope, at the bottom of which, that is towards the object glass, there is a magnetic needle, which assumes its proper direction, when the telescope is placed upon the side which that object glass forms.

To construct this telescope, provide a turned tube of ivory, wider towards the end where the object glass is placed; but the ivory must be of sufficient thinness to admit the light through to the inside. The narrow end is furnished with an eye glass, which serves to show more distinctly the inside of it. The other end also is furnished with a glass, which has the appearance only of an object glass, the posterior surface of it being opake, so as to serve for the base or bottom of a sort of compass or magnetic needle, which turns on a pivot fixed in its centre. When the telescope rests on the end containing the object glass, this needle assumes a horizontal position,

and points towards the north, or towards a magnetic needle in the neighbourhood. It is necessary also to have a real telescope, similar in appearance to the other, in order that it may be shown instead of it, which may be done by dexterously substituting the one for the other.

When you wish to employ the pretended magic telescope, place it with the object glass downwards upon any thing you intend to examine, and if there be a magnet, or piece of magnetised iron below it, the needle will turn to that side.

§ II.

Several figures being given, which a person has arranged close to each other in a box, to tell through the lid or cover what number they form.

If you are desirous of employing the ten cyphers, take ten small squares, of an inch and a half on each side, and on the upper face of each make a groove; but let these grooves be in different directions; that is to say, the first intended for the number 1 must proceed directly from the top to the bottom; the second must deviate to the right, so as to form an angle equal to a tenth part of the circumference; the third an angle of two tenths; and so of the rest; which will give ten different positions. Then introduce into these grooves small bars of steel, well magnetised, taking care to turn their north poles to the proper direction; cover these grooves and the face of the squares with strong paper, in order to conceal the bars. You must also provide a narrow box, capable of containing in its breadth one of these squares, and of such a length that they can all be arranged in it.

Then desire a person in your absence to take several of these squares, and arrange them in the box in any manner, at pleasure, so as to form any number whatever, and to

shut the box; after which you are to tell the number which has been formed.

Deposit your pretended telescope on the place of the first square, that is on the left, if the figure below it be unity; the needle will turn in such a manner that the north point or pole will be before you. If the figure be 4, it will turn to the fourth division of the circle, which is equally divided into ten parts; and so of the rest. It will thence be easy to discover the figure in each place, and consequently to tell it.

A word written in secret, with given characters, may be discovered in the same manner; also an anagram, formed of a proposed word, as *Roma,* which gives *amor, mora, orma, maro,* &c; or a question which has been selected from several persons, and put into the box. In short, this trick may be varied in a great many ways, exceedingly agreeable, but all depending on the same principle.

The box of metals, for example, is only a similar variation of the same trick. You put six plates of different metals in a box, and bid a person take any one of them, and put it into another box, and shut it. You may then easily tell which one he has taken. These plates are of such a form, that they can occupy in the small box only one position. Each of them, that of iron excepted, contains in its thickness a magnetic bar, arranged in situations which are known, and these situations are discovered by means of the pretended magic telescope; consequently the nature of the metal must be known. No magnetic bar is placed in the plate of iron, because this would be useless; but one side of the plate may be magnetised, or if it be not magnetised, the indeterminate direction of the needle will announce that it is iron.

§ III.

The Learned Fly, or the Syren.

This trick is somewhat more complex than the preceding, and depends partly on philosophical principles, and partly on a little deception. You must provide a table, with a box sunk in its thickness, and the box must be furnished with a broad brim, inscribed with numbers, the hours of the day, or answers to certain questions. You then desire a person to point out a number, or to name any hour in the day, or to ask what o'clock it is, or to select any one of certain questions written upon cards which you present to him. A fly, a syren, or a swan, floating in water, indicates, in their order, the figures of this number, or answers the question proposed.

All this is performed by means of a strongly magnetised bar, supported by a brass circle, concealed in the rim of the bason, which contains the water. It is evident that if the motion, necessary to point out the letters, or numbers required for the answer, can be given to this bar, the fly or syren, placed on a small boat containing another magnetic bar, will proceed towards it, and appear to answer the question. Such are the philosophical principles of this trick, the deception is as follows.

The table, which is some inches in thickness, is hollow, and the cavity contains a certain mechanism put in motion by a string, which, passing through the feet of the table, traverses the floor, and is conveyed into a neighbouring apartment, separated from that where the trick is exhibited, only by a very slight partition. This string terminates in a sort of table, on which are marked the divisions of the bason; and the whole is combined in such a manner, that when the end of the string is brought opposite to a certain figure, such as 4 for example, the magnetic bar will be under the 4, inscribed on the edge of the vessel.

When the syren then is desired to tell what o'clock it is; the person behind the partition, and who hears the question, has nothing to do but to pull the string, and to bring the end of it opposite to the required hour on the table, which is before him. The magnetic bar will arrange itself below, and the tractable syren, beginning to move, will go and point out the hour.

If a question has been selected; the person who exhibits the trick repeats it under a pretence of interrogating the syren. The confederate, who hears it, causes the magnetic bar to move to the answer.

It would not be difficult to establish between both a secret communication of such a nature, that, without speaking, the syren should appear to guess the question, and to give an answer to it.

The principal works on the magnet are, A treatise *de Magnete* by Gilbert, an English philosopher, printed in 1633: it contains traces of that spirit of observation which has since caused philosophy to make so great a progress. The *Ars Magnetica* of Kircher: this is a kind of encyclopædia of every thing written before the author's time on that subject, enlarged by a great many of his own ideas, the greater part of which however display more imagination than judgment. The *Magnetologia* of Father Leothaud, 1668, in 4to: a work of very little importance. Father Scarella's treatise, entitled *de Magnete*, in four volumes, quarto, printed at Brescia, in 1759, may supply the place of all the preceding, as it contains a comprehensive account of every thing useful or solid, said or written on the magnet, till that period; to which the author, a very enlightened philosopher, has added his own ideas. The small treatise on Artificial Magnets, translated from the English, with an historical preface by the translator, will make the reader fully acquainted with that part of the theory of the magnet; or, in want of it, recourse may be

had to the *Memoire sur les Aimants artificiels*, by M. Antheaume, which gained the prize proposed by the academy of Petersburg in 1758. Several papers also by M. Dutour, inserted in the *Memoires presentés à l'Academie, par des Sçavans etrangers*, deserve to be known, and to be studied, by those who may be desirous of cultivating and enlarging this theory.

MATHEMATICAL

AND

PHILOSOPHICAL

RECREATIONS.

PART THIRTEENTH.

Of Electricity.

ELECTRICITY is an almost inexhaustible source of singular and surprising phenomena, which must excite the curiosity of the most indifferent observer of nature. What indeed can be more extraordinary, and at the same time more difficult to be reconciled with the known laws of natural philosophy, than to see mere friction excite, in certain substances, the power of attracting and repelling such light bodies as are near them; to see this power communicated, by contact to other bodies, and even to very great distances; to see fire issue from a body in that state; and a thousand other phenomena, the enumeration of which would be too tedious? We shall mention only the famous experiment of Leyden, where a rank of persons, holding each other by the hands, or having a communication by means of an iron wire, or rod, suddenly receive from an

invisible agent an internal commotion, which might even be so violent as to kill those who experience it.

It must however be allowed, that the case has not yet been the same with electricity as with magnetism. The latter, by the invention of the magnetic needle, has served to render navigation more secure, and to discover the new world, a source of new riches, new wants, and of new evils to the old one. But electricity has not yet produced any thing of so much importance to mankind, and to the arts, if we except the analogy now fully proved between the electric fire and lightening: an analogy which has given rise to a pretty sure preservative from the effects of that dreadful meteor; for in regard to the cures effected by electricity, it must be acknowledged that they are either rare, or not well ascertained.

But we must not treat all researches on this subject as useless; for when we consider the phenomena exhibited by electricity, we cannot help allowing that it is one of the most general and most powerful agents in nature. Is it possible to deny, that the identity of the electric fire and lightening is a noble and grand discovery? What can we say of a multitude of other analogies observed between electricity and magnetism, the nervous fluid, the principle of vegetation, &c. They seem to promise a copious harvest to those who shall continue to cultivate this fertile field.

§ I.

Of the Nature of Electricity. And the distinction between bodies Electric by Friction or by Communication.

Electricity is a property which certain bodies acquire by friction, that is to say the power of attracting or repelling light bodies which may be near them. If you rub, for example, a stick of Spanish wax, with your hand, or rather with a piece of cloth, and then make the wax pass within

a few lines of small bits of paper or straw, you will see them rush towards the wax and adhere to it, as if cemented, until the virtue acquired by the friction is dissipated. The ancients had observed that yellow amber, when rubbed in this manner, attracted light bodies: hence the name of *electricity;* for they called that substance *electrum.* But their observations went no farther.

The moderns have found the same property in a great many other bodies; such as grey amber, and in general in all resins, which can bear a certain degree of friction, without becoming soft; as sulphur, wax, jet, glass, the diamond, crystal, the greater part of the precious stones, silk, woollen, the hair of animals, and very dry wood.

In regard to bodies which do not acquire electricity by friction, it has been observed that they can acquire it by communication; that is to say by contact, or by being brought very near to those of the first species; and that they can transmit it, by the same means, to other bodies of the same nature. Those bodies, which cannot be rendered electric by friction, are metals, and water, either liquid or congealed*; also earthy and animal bodies. But we must observe that, properly speaking, metals and the aqueous fluid are the only true conductors of electricity; and that the rest are not so, unless they participate in the metallic nature, or contain more or less moisture. Electricity seems even to prefer the metallic bodies, for transmitting itself from one body to another. If you place a body then of the latter kind, such as a metal rod, or a piece of moist wood, in the neighbourhood of a body, or in contact with a body of the first kind, electrified by friction, and with precautions to be mentioned here-

* It has since been observed that glass heated till it becomes red or more, and flame, are conductors of electricity. On the other hand water, which in its state of fluidity is a conductor of electricity, ceases to be so when strongly frozen.

after, it will itself become electric; which may be readily seen by the motion it will communicate to light bodies in its neighbourhood.

All bodies then are susceptible of being electric, but in two different ways: one kind are in some measure electric of themselves, as that virtue can be excited in them by friction; for this reason they are called *electric per se:* the other kind are electric only by communication, and for this reason they are commonly called electric by communication, or *non electric;* but it would be better to call them *conductors of electricity:* and this is the appellation which we shall most frequently employ.

It may be here proper to observe, that those of the first class are not susceptible of receiving electricity by communication, or they receive it in that manner with difficulty. Hence it happens that, in the experiments we are about to describe, the bodies to be electrified by communication, must be placed either on cakes of resin, or be suspended by silk strings; otherwise the electricity produced in them would be immediately dissipated, by the contact of bodies susceptible of being electrified by communication, with which they might be in contact.

§ II.

Description of the Electric Machine, and of the apparatus necessary for performing Electrical Experiments.

When philosophers began to cultivate the theory of electricity, they employed nothing for the purpose of exciting it but a glass tube, about 3 inches in diameter, and from 25 to 30 inches in length. It was rubbed lengthwise and in the same direction, with the bare hand provided it was very dry, or wrapped up in a bit of flannel or cloth; and this tube was afterwards presented to the body intended to be electrified. It was in this manner that Gray and Dufay made their first experiments.

A globe suspended between two wooden pillars, which was made to revolve rapidly by means of a handle or wheel, was afterwards substituted instead of this tube: the dry hand was applied to the globe thus arranged, or it was made to rub against a cushion: this operation excited the electricity, which was collected as we may say by means of a metallic fringe suspended from the globe, or disposed in some other manner.

These machines were succeeded by one much simpler. It consists of a foot or stand A, pl. 7 fig. 40, upon which are raised two uprights, B and C, secured and united at the top by means of the circular piece D. These uprights must be of a greater or less height, according to the diameter of the circular glass plate E, placed between them; for the edge of the plate must not approach too near the wooden frame, either at the top or the bottom.

This circular plate of glass E, is the most essential part of the machine. It has a hole in the centre, of sufficient size to admit a steel axis, which turns in the two supporters, and towards the side C, is continued outwards, where it terminates in a square extremity, fitted into a handle, which serves to turn the plate.

Leather cushions, stuffed with hair, are applied to the supporters on each side, both at the top and bottom; so that the glass plate, as it revolves, is rubbed by the cushions to the distance of some inches from its edge.

On the longitudinal part of the stand is placed a conductor, supported by a glass foot in the form of a column. This conductor is a copper cylinder, terminating at one end in a ball G, of the same metal, and having at the other end, two arms bent almost in a semicircular form. At the extremities of these arms are two hemispherical figures, H and I, which present to the glass plate their circular bases, furnished with four sharp steel spikes, all of the same

length. The foot of the conductor can be made to advance or recede on the bottom part of the machine, which supports it, in such a manner that the before mentioned spikes can be brought nearer to, or removed from the surface of the glass plate; for it is these spikes, as will be seen hereafter, that attract the electric fluid, excited or put in motion by the friction of the small cushions on the circular glass plate.

When you are desirous of producing electricity; place the machine on a firm table, and make it fast by means of screws; then fix the conductor in such a manner, that the spikes may approach very near to the glass plate, and put the latter in motion by turning the handle. The conductor will almost immediately exhibit signs of electricity, either by emitting sparks on the finger being applied to it, or by attracting and repelling light bodies placed near it.

Remarks.—Some other instruments are necessary for electric experiments: but we shall here mention those only which are commonly used, reserving the description of the rest, till we come to speak of the different experiments in which they are necessary.

I. You must be provided with a few stools, either square or circular, covered with resin, about 15 or 18 inches in breadth; and, the better to ensure the effect, they may be made to rest on four glass bottles or feet. These stools serve to insulate the persons or bodies intended to be electrified.

II. As it is sometimes dangerous to draw out the electricity by the finger, it will be proper to have an instrument, called the discharger, which is a circular piece of metal, pl. 7 fig. 41, affixed by the middle to a handle, made of glass or Spanish wax; but the first is preferable and stronger. By touching bodies, electrified in the highest degree, with one of the balls of this instrument,

sparks may be extracted from them without danger; because the glass handle intercepts the passage of the electricity, from the discharger to the person who holds it.

III. You must have also a chain of metal, or of several pieces of wire connected together. This chain serves for transmitting the electricity to a distance from the first conductor, HGI; which is done by suspending it from silk cords, attached to the ceiling, or extending it between two supporters.

IV. It will be proper to provide likewise a long tube of metal, or of gilt pasteboard, three or four inches in diameter. This tube, having a communication with the conductor by means of a chain, forms a second conductor, which becomes charged with a great deal of electricity, and may be employed in a variety of experiments. The longer and larger this tube is, the greater will be the quantity of electricity with which it will be charged. For reasons which will be mentioned hereafter, it is necessary that it should have no points or sharp eminences.

V. A few glass plates are also necessary, to insulate those bodies which may be required to retain their electricity.

VI. You must provide likewise a few pieces of metal, some pointed and others terminating in spherical or round ends; some affixed to glass handles, and others furnished with handles of some substance that transmits electricity, as before mentioned.

VII. The cushions must be occasionally rubbed over with a kind of amalgam, which serves to increase the friction. That which appears to answer best, is an amalgam of tin and mercury, such as that placed at the back of mirrors, mixed with one half of chalk or Spanish whitening, the whole reduced to an impalpable powder.

Such are the principal parts of the apparatus necessary for the most common electric experiments; to which

we shall now proceed, beginning with those that are simplest.

EXPERIMENT I.

The Electric Spark.

Every thing being arranged, as above described, and the air in the apartment being dry, put the machine in motion. If a person then present his finger to the conductor, at the distance of two or three lines, or more, according to the strength of the electricity, two sparks will proceed at the same time, from the conductor and the finger, accompanied with a snapping noise, which will even occasion some pain. When the person, whom we suppose to be on the floor, touches the conductor, it will give no more signs of electricity, because he will then be in communication with the whole mass of non-electric bodies with which he is in contact.

EXPERIMENT II.

Communication of Electricity to Several Persons.

Cause the person, above mentioned, to stand on a cake of resin, by which means he will be insulated from the floor, and put the machine in motion. This person, as well as the conductor, will thus be electrified; so that all those, not in the same state, who happen to touch each other, will elicit electric sparks.

Twenty persons, and more, may be electrified in this manner, provided they are insulated.

EXPERIMENT III.

Attraction and Repulsion.

Present to the person electrified, or to the conduc[tor] some gold leaf or tin-foil, or bits of straw, or paper[,] other light non-electric bodies. When at a proper dist[ance] you will see them dart towards the electrified body

as soon as they have touched it, they will be repelled. If you then receive them on a non-electric body, as soon as they touch it, they will return towards the electrified body, and will be again repelled; and so on alternately.

EXPERIMENT IV.

Some Electric Amusements, founded on the preceding property. The Gold Fish; the Electric Dance; the Luminous Rain.

The property which electric bodies have of repelling each other, when in that state, and of attracting each other when one of them only is electrified, has given rise to several very agreeable amusements, which we shall here explain.

I. Cut a piece of strong gold leaf into the form of a rhombus, two opposite angles of which may be very obtuse, while the other two are very acute. Present this metallic leaf to the conductor, in such a manner that one of the acute angles shall be first raised, and immediately put below it a metallic plate. You will then see the leaf place itself between the conductor and the plate, and remain in that state almost motionless.

Cut leaves of metal of this kind into the shape of the human figure, having an acute angle at the top, like a pointed cap, and lay them flat on the plate: if you then place them below the conductor, on another plate, you will see them start up, leap towards the conductor, then fall down, turning round with more or less rapidity, so as to represent a kind of dance; and if the experiment be performed in the dark, you will observe luminous aigrettes dart alternately from the head and the feet, which will form a very agreeable spectacle.

II. Cut a piece of the same gold leaf into a figure very much lengthened on one side, but on the other much less acute; to this part if you choose you may give the form

of the head of a fish. If you lay hold of it by the acute angle, and present the obtuse one to the conductor, at the distance of a foot, if the electricity be strong, it will escape from your fingers, and will fly with an undulating motion towards the conductor, above which it will place itself at the distance of the eighth part of an inch, turning towards it the obtuse angle. Sometimes it will approach so near as to come into contact with it, and will be immediately repelled, forming the representation of a small fish going to attack or bite the conductor. This amusement therefore has been called the *Gold fish.*

III. The luminous rain may be produced in the following manner. Suspend from the conductor a circular plate, 5 or 6 inches in diameter; then provide a metallic plate in the form of a saucer, and surround the edge of it with a glass cylinder 5 or 6 inches in height. Cover this plate with very fine light shavings of metal, and place it under the plate suspended from the conductor. When the latter is strongly electrified, you will see all these small leaves of metal ascend from the lower to the upper plate, and sparkle; being then repelled to the lower one, they will again sparkle, or will sparkle between the plates, when one which is electrified meets with one not electrified: by these means the glass cylinder will be filled with a great deal of light, which will exhibit the appearance of a shower of fire.

EXPERIMENT V.

Repulsion between bodies equally electrified.

Suspend from the extremity of the conductor two threads of any non-electric matter; such as flax, hemp, or cotton, which will hang down perpendicularly, and touch each other, if their upper extremities are in contact If you then work the machine, and produce electricity i the conductor and these threads, you will see them rep

each other, and form an angle of greater extent as the electricity is stronger. When the electricity decreases, they will approach each other.

This experiment proves a very important fact in the theory of electricity; which is, that two bodies, similarly electrified, repel each other: and hence we are enabled to explain several electric phenomena and amusements.

EXPERIMENT VI.

Construction of an Electrometer.

By the preceding experiment we are furnished with the means of determining the strength of electricity; and the two threads, above mentioned, may be considered as a sort of electrometer. However, as two threads of this kind may be subject to various movements, independent of electricity, electricians have almost universally adopted the following instrument, which is equally simple.

The whole of this machine consists of two small balls, two lines in diameter, made of cork or the pith of the elder tree, and fixed to the two extremities of a thread capable of conducting electricity. This thread is made to pass over the conductor in such a manner, that the two balls hang at the same height. As soon as electricity is produced in the conductor, and consequently in the small balls, they diverge from each other, and the magnitude of the angle formed by the threads will convey some idea of the intensity of the electricity. We say conveys an idea of this intensity; for it is not possible, either by this or any other method, with which we are acquainted, to determine when the electricity is double, triple, or quadruple, &c; but we are at least enabled to conclude, that one degree of electricity is greater or less than another; or that two degrees of electricity are equal, according as the divergency of the balls is greater or less or the same, which in general is all that is necessary to be known.

EXPERIMENT VII.

To kindle spirit of wine by means of the electric spark.

When a person is electrified, if another standing on the floor approaches him, having in his hand a spoon filled with spirit of wine, well dephlegmated, and somewhat heated; and if the electrified person presents his finger to the spirit of wine, or, what is still better, the point of some blunt instrument, or the point of a sword, an electric spark will proceed from the liquor, and set it on fire.

If the painful sensation produced by the electric spark could leave any doubt of its being real fire, this experiment must be a convincing proof of it.

EXPERIMENT VIII.

Properties of Sharp Points or Spikes.

Instead of a conductor, such as that above described, if you employ an angular bar of metal, or a bar terminating in one or more points; on approaching your finger to one of the angles or points, when the machine is put in motion, but not in such a manner as to produce an electric spark, you will feel something exhaled like a gentle breath of wind, and even with a sort of crackling noise.

But, if the experiment be performed in the dark, you will enjoy a very beautiful spectacle; for when the electricity is strong, you will see luminous gerbes issue from the angles of the conductor, and these gerbes will be considerably increased on presenting your finger to them.

You will discover, at the same time, that the cause of this gentle breath, accompanied with noise, is nothing else than the eruption of the electric fluid, whatever it may be, from the electrified body, which rushes towards your finger. Hence it follows that it is a body, since it re-acts against another body.

It is to be observed, that when the electrified body is

angular, it loses much sooner the electricity which has been communicated to it. These angles and points seem to be so many spontaneous dischargers of the electric matter; they ought therefore to be avoided in bodies intended to be electrified, and in which you are desirous to maintain the electricity as long as possible.

EXPERIMENT IX.

Difference between Pointed, and Blunt bodies.

Electrify strongly in the dark a common conductor, or any other body whatever, not angular, and when it is strongly charged, present to it a blunt body, such as the finger or a spike rounded at the end, holding it so near it as to elicit the electric spark. But if you present to it a very sharp instrument or spike, you will see a luminous star formed at the extremity of it, even before it is brought so near; and if the electrified body does not every moment receive a fresh supply of electricity, it will thus soon be deprived of it.

If this spike be supported by a cake of resin, it will itself become electrified; but the electricity of the conductor will not be entirely destroyed.

It appears from this experiment, that if the luminous gerbes in the preceding one are formed by a matter which flows off from the electrified body, the case in the present instance is contrary: they are formed by a matter which throws itself towards the point presented to the electrified body. What indeed can be said when we observe a non-electrified body become so by this method; but that the electric matter, fire, or fluid, whatever it be, proceeds from the electrified body to another, especially as it is certain that the former thereby loses either the whole or a part of its electricity, according to circumstances, that is to say, according as the other stands on the floor or is insulated?

But however this may be, the following is a singular and

remarkable property of pointed bodies. The extraordinary use which Dr. Franklin made of it will be shown hereafter

EXPERIMENT X.

Method of knowing whether a body be in a state of electricity.

When two bodies are equally electrified, if they be brought into contact with each other, no sign of electricity will be manifested between them, by sparks or any electric emanation.

This may be easily proved; for if a person electrified by touching the conductor gives his hand to another electrified in the same manner, there will be no spark.

These two persons however may know that they are electrified by the following sign. Let each of them take in his hand a thread, made of any non-electric substance, or a cork ball suspended from such a thread; if these two balls or two threads repel each other, it may be concluded that the persons are in an electric state.

EXPERIMENT XI.

Distinction between the Two Kinds of electricity.

Provide two electric machines, one of them constructed as they were formerly, that is, with a glass globe, and the other with a globe of sulphur instead of glass: if a conductor be then electrified by each of them at one of its ends, you will see with astonishment, if the machines are moved with equal velocity, that scarcely any sparks can be extracted from the conductor.

The case certainly would not be the same, if the conductor were electrified by means of two glass globes at the same time, or with two globes of sulphur; the sparks would be much stronger than if one globe had been put in motion.

Remark.—This experiment, which Dr. Franklin says

he made at the request of his friend Mr. Kinnersley, seems to me to leave no doubt in regard to the difference between electricity communicated by glass, and that communicated by sulphur; and consequently establishes the distinction of vitreous and sulphureous or resinous electricity; a distinction before asserted by Dufay.

Dufay indeed had observed, that though two bodies electrified by glass or sulphur mutually repelled each other, yet when one of them was electrified by the one of these substances, and the other by the other, instead of repelling, they attracted each other. We do not think that any stronger proof of the two states can be desired.

If to this be added the above experiment of Dr. Franklin, how can we elude the consequence which he and Dufay deduce from it? For, it is well known that two bodies equally electrified by a glass globe may touch each other without producing a spark, and without the electrical virtue being diminished in either of them. Since these bodies then electrified, one by the glass and the other by the sulphur, mutually destroy each other's electricity, the one must be of a nature contrary to the other, and entirely different.

Some able philosophers however, notwithstanding these reasons, persist in rejecting this distinction; but in our opinion they labour under the influence of prejudice, or, being seduced by peculiar ideas, keep their eyes shut against the light. We are inclined to think, that if the abbé Nollet had not previously formed his system on electricity, he would have adopted the distinction of the two kinds.

However, as this is the proper place, we shall here give an idea of Dr. Franklin's system in regard to electricity. According to this celebrated philosopher, all bodies in their natural state contain in their substance, or on their surface, a certain quantity of a fluid, which is the electric

fluid. The air, which when dry is not a conductor of electricity, prevents its dispersion. But the friction of certain bodies, glass for example, collects on the surface of them a greater quantity of the fluid; so that if the glass be in contact, or very near to a body electric by communication, such as a mass of iron, the fluid accumulated on the surface of the glass tends to pass into the mass of iron, in order to preserve an equilibrium. By these means this mass acquires a greater quantity of the electric fluid, and is then electrified *positively*. But if the electric body instead of acquiring by friction a greater quantity of the electric fluid, loses some of what it had, as is the case with sulphur, the body in contact with it will lose a part of its own natural electricity, and will then be electrified *negatively*. The one will have more electric fluid than it has in its natural state, and that of all the bodies which have a communication with the earth; the other will have less. Such is the nature of *positive* and *negative* electricity.

It must however be allowed, that it does not clearly appear how friction should accumulate on the surface of the rubbed body, a greater quantity of the electric fluid. It is not even known whether the effect of friction is to accumulate the fluid on the glass, or to diminish the quantity of it; whether it lessens it on sulphur and resins, or increases it. Hence it is uncertain which is the *positive* and which the *negative* electricity; but we know beyond a doubt, that their effects are contrary, and this is sufficient. Several reasons however make it probable, that the electricity, produced by the friction of glass, is the *positive*, or accumulated electricity.

Notwithstanding this uncertainty, Franklin's theory has a great advantage over that of the abbé Nollet. The latter supposes a matter diffused throughout all bodies, and even in the atmosphere, which with all other electricians he calls the *electric fluid*. In this he agrees with Dr. Frank-

lin; but he thinks the effect of friction is to make this fluid sometimes issue from the pores of the body rubbed, and sometimes to attract it. Electricity therefore, or the electric fluid, is sometimes *effluent*, and sometimes *affluent;* and it is by means of this effluence or affluence that this philosopher explains all the phenomena of electricity. But the great defect of this system is, that every thing in it is, as we may say, arbitrary. What cannot be explained by the affluent fluid, may be explained by the effluent. These are the different matters of Descartes, or his subtile matter, which may be applied to every thing. On the other hand, in the system of Franklin, the effects are much better connected with the causes, even supposing them hypothetical. Why does a spark issue when a body, positively or negatively electrified, is brought near to another which is in its natural state? The answer is easy. The electric fluid accumulated on the one side, and extended in the form of an atmosphere, as it were, on the surface of a body, puts itself in equilibrium, when it comes in contact with another electric atmosphere less condensed: the fluid divides itself equally between the two bodies; which cannot be done without an exceedingly rapid movement that produces light. But what is most remarkable in the hypothesis of Franklin, and is almost the touchstone of truth, is, that even the bare description of the simplest experiment, to those who have properly comprehended this hypothesis, is sufficient to enable them immediately to guess the result. The case is not the same with the system of the abbé Nollet: none of the effects about to be produced are foreseen, and if every thing be explained, it is because no effect is connected with its cause. Had the phenomenon been quite contrary, it might have been explained with the same ease: effluence could be employed instead of affluence, one is the remedy or supplement of the other.

We must however acknowledge, that there are some facts difficult to be reconciled with the motion of the electric fluid, which is a necessary consequence of Franklin's system.

For example, when the finger is brought near to a body, electrified either positively or negatively, why do we see a double spark proceed from each of these bodies? It would appear that it ought to proceed only from that which is endowed with positive electricity.

In a certain experiment, in which a quire of paper is pierced by the electric spark, why is the rough edge of the hole turned in a direction contrary to that in which it ought to be, if the fluid accumulated on the surface of the electrified body were the only one that proceeded to the body negatively electrified? We shall omit several others, which have been remarked by the partisans of the abbé Nollet, and only observe that there is still reason to suspend our opinion on the mechanism of this phenomenon.

EXPERIMENT XII.

The Leyden Flask, and Shock.

There is not perhaps in natural philosophy a phenomenon more astonishing than that which we are about to describe. Provide a flask of very thin white glass, with a long neck, and fill about two thirds of it with water, or metallic filings, or raspings of lead. Close it with a cork stopper, and introduce into it through the cork, an iron wire, so as to be immersed with one end in the water or filings, while the other projects some inches beyond the cork, and terminates in a blunt or crooked extremity.

When the flask is thus prepared, lay hold of it by the belly, and present the iron wire to the conductor of the electrifying machine while in action. By these means the flask will be *charged*. While the wire is in contact with the conductor, if you then endeavour to touch the latter,

or the iron wire, with the other hand, you will experience throughout your whole body a violent shock, which will seem to affect more particularly, sometimes your breast, sometimes your shoulders, and sometimes your arm or wrist.

The same effect will be experienced if you retire, holding the bottle by the belly with one hand, and touch the iron wire with the other.

Nay, a chain may be formed of as many persons as you choose, holding each other by the hand, and without being insulated. The first person holds the bottle in his hand, or only touches it, while the iron wire is in contact with the conductor; and the last touches the conductor: all those who form the chain will experience the before-mentioned shock at the same instant. When the flask is of considerable size, and has been well charged, the shock is sometimes so violent, that those subjected to it suffer a momentary loss of respiration. The celebrated Muschenbroek, to whom M. Cuneus exhibited this phenomenon, which he had discovered by accident, received, according to every appearance, a violent shock, since in announcing it to the French philosophers, he protested that he would not expose himself to it a second time, for the whole kingdom of France. It is however probable that he afterwards became bolder. As this singular experiment was first performed at Leyden, it is generally called the *Leyden experiment*, and the bottle, so prepared, is distinguished by the name of the *Leyden flask* or *phial.*

The French philosophers once formed a chain 900 toises in length, by means of 200 persons, all connected by iron wires; and all these persons experienced the shock at the same instant. Another time they tried to transmit the shock along an iron wire 2000 toises in length, and the experiment succeeded, though the wire passed over the wet grass, and newly ploughed land. In short, they com-

prehended in the chain the water in the grand bason of the Tuilleries, which is nearly an acre in extent, and the shock was transmitted very well across it.

Remarks.—I. As some inconvenience resulted from the weight of the water or filings, put at first into the flask, the idea was afterwards conceived of covering the inside of it with a metallic coating. This may be done in several ways. The most simple is to pour into the bottle strong gum water, and to moisten with it the part intended to be coated. The superfluous gum water is then poured out, and very fine copper filings are put into the bottle: these filings adhere to the gum water, and form an internal coating, which must be in contact with the iron wire, that the bottle may be charged.

The effect of the Leyden flask may be increased also by covering a great part of the outside of it with tin-foil.

II. The flask may be charged in another manner, that is to say, externally. For this purpose, hold it suspended in the one hand by the hook or iron wire on the outside, and bring the inside into contact with the electrified conductor. If it be then touched on the outside with the other hand, you will experience a shock. You may form, in like manner, a chain of several persons, the last of whom, or the one farthest distant from the person who holds the iron wire, by touching the outside of it, will produce the same phenomenon throughout the whole chain.

III. Dr. Franklin observed the following very singular circumstance, which takes place in performing the Leyden experiment: if you are desirous of charging the inside of the jar or flask, the outside must communicate with some body which is a conductor of electricity; for if the flask be placed on a cake of resin, it will be in vain to electrify, by the conductor of the machine, the wire which touches the water or metallic coating in the inside: the flask will

not become charged. Is it necessary, before it can be charged, that in proportion as the electricity is accumulated on one side, it should be diminished on the other? This is the conclusion which Dr. Franklin forms, and which appears indeed to be agreeable to reason. But how is it that the electric fluid is expelled from one side, while the other becomes more highly charged with it? This appears to us to be a considerable difficulty.

IV. The jar seems to be impermeable to electricity, at least when cold, or when it has only the temperature of the atmosphere. Dr. Franklin once tried to grind away the belly of a charged flask, which was of the usual thickness. He ground down $\frac{5}{6}$ of its thickness, without its being discharged, which would have been the case if the fluid in the inside had communicated with that on the outside. It is to be wished that this philosopher had continued to diminish the thickness, until a discharge had taken place.

But when the glass is dilated and softened by a heat which brings it nearly to a state of fusion, it then not only becomes a conductor of electricity, but the charged jar discharges itself spontaneously.

V. If a chain, suspended from the conductor, be introduced into the flask while held in the hand, it becomes charged in the like manner; but if the flask be lowered in such a manner, as no longer to support any portion of the chain, it then gives no more signs of electricity.

There is reason thence to conclude that the electricity, with which the inside of the bottle is charged, ought to have for its support some non-electric matter, or a conductor of electricity. It would be in vain to attempt to charge an empty bottle, or a bottle not covered in the inside with a metallic coating.

VI. If the inside of the bottle be charged, making it communicate by the hooked wire with a conductor positively electrified, the outside will then be negatively

electrified; for the outside will attract the small ball of cork suspended from the conductor, while the hook of the flask repels it. But it is well known that an electrified body repels another electrified like itself; it attracts only bodies not electrified, or electrified in a contrary sense. Since the outside of the bottle then, electrified by the hook, attracts the small ball of cork, the electricity of which is of the same nature as that of the conductor, or of the inside of the jar, the exterior electricity must be of a nature entirely different.

VII. If you have two equal flasks, equally charged, and in the same manner, and if you then bring them near to each other, so as that the hooks or the sides of them be in contact, they will not be discharged; but if you apply the hook of the one to the side of the other, a discharge will immediately take place.

If one of the flasks be charged by a globe of sulphur, and the other by a globe of glass, if the hook of the one be then made to approach the hook of the other, or the side of the one the side of the other, they will be discharged.

VIII. If several persons, instead of holding each other by the hands, present to each other the tips of their fingers, at the distance of one or two lines, at the moment when the last touches the conductor, you will observe between all the fingers an electric spark, and each will experience a shock.

IX. If the persons, instead of holding each other by the hands, form a communication with each other by holding glass tubes filled with water, and stopped with a cork, through which passes an iron wire immersed in the fluid, and which is in contact with each person, at the moment when the last person touches the conductor, or the wire immersed in the flask, you will perceive a train of light in the water in each tube, which will be wholly illuminated by it.

X. The chain being formed, if one or two or more persons form a new one, connected on one side with those who form the first chain, and on the other side with another person of the same chain, those of the latter will experience nothing; the electric fluid seems to proceed from one end to the other of the first chain, by the shortest route.

EXPERIMENT XIII.

Another method of giving the shock, namely, by an electric pane of glass. To pierce a quire of paper by the electric spark.

Does the singular effect observed in the preceding experiment depend on the figure of the Leyden jar, or merely on the nature of the glass? This question, which naturally occurs, is answered by the following experiment: it proves that the effect alluded to depends entirely on the nature of the glass.

Take a pane of glass of any dimensions, and cover both sides of it with tin-foil, leaving on each side a border of the glass uncovered; place the glass horizontally on a non-electric supporter, and make the chain of the conductor to fall on its surface. If you then put the machine in motion, the glass will become charged like the Leyden flask; that is, if resting one side of the discharger on the upper surface, the other be applied to the lower one, you will extract a strong and powerful spark. If the glass be large, it will be dangerous to touch one of the surfaces with the one hand, and the other with the other.

If you are desirous to pierce a quire of paper with the electric spark, you must proceed as follows. Extend a piece of iron wire on a table, and place over it the pane of glass, so that the end of the wire shall touch the coating of the lower side: on the upper coating place a quire of paper; then electrify the upper surface by means of the

chain of the conductor, which must be made to fall upon it. When you think the electricity is very strong, bring one of the ends of the discharger into contact with the wire, and apply the other end to the paper. A very strong spark will issue from it, with a noise like the report of a pistol; and the quire of paper will be pierced through and through.

If the experiment be made with a piece of glass of about 35 inches square, 150 sheets of paper, and even more, may thus be pierced.

This method of performing the Leyden experiment is attended with the advantage of greatly increasing its effect; for the surface of the largest flask can contain no more than two or three square feet. But a plate of glass, 36 inches in every direction, contains 9 square feet, and the effect is thereby increased in the same proportion.

It may be easily seen, that, in performing this experiment, you must take care not to stand in the circle between the upper and lower surface, otherwise you might run the danger of being killed.

EXPERIMENT XIV.

Means of increasing, as it were indefinitely, the Force of electricity.—The Electric Battery.

A single flask, charged with electricity, does not produce a very great effect; but this effect is increased according as the volume of the jar is augmented. It would however be inconvenient, and perhaps impossible, to obtain jars beyond a certain size; for this reason several jars have been substituted in the room of one; but the united effect of them is exceedingly dangerous, unless great precautions are employed.

For this purpose, instead of long-necked flasks, several large cylindric jars, of a much greater length than breadth, must be employed. It is not necessary however that their

liameter should be very great, because cylinders of a mall diameter have, in proportion to their solidity, a greater surface, and surface is what is required to be in-reased. They are lined on the inside with a coating of in-foil, which covers the bottom and sides to within two nches of the brim. And they are coated, in the same nanner, on the outside; after which, they are arranged lose to each other in a box, lined also in the inside with in-foil and copper-filings. The tin-foil communicates with wire ring projecting from each jar, and to these rings is ttached the chain, by means of which a communication is stablished between any body and the exterior part of the attery.

To establish a communication with the inside of the jars, piece of iron wire, twisted at the lower end, and ter-minating at the upper end in a ring, must be made to pass hrough the cork stopper of each jar, so as to descend to he bottom of it. A metal rod, having a ball at each end, asses through all the rings of the same row; and, to stablish a communication between the rods, the chain of he conductor is made to rest on them: in consequence of his arrangement, you may charge, if necessary, only one two rows of the jars, by making the chain to rest on one d only, or on two, &c.

Such is the construction of an electric battery, the re-presentation of which, supposing it to consist of only nine rs, each 15 inches in height, 3 inches in diameter, and ntaining 12 inches of coated surface, which gives al-gether 6¾ square feet, is seen pl. 7, fig. 42. A similar ttery of 64 jars would give 48 square feet, and yet form ly a box of two feet some inches square, and from 15 to inches in height. The effect of such a battery would prodigious.

The method of using this apparatus is as follows. To arge the jars, make the chain, which proceeds from the

conductor of the machine, to rest on the rods, and turn the glass globe or plate for some time. Experience will show how many turns of the machine will be necessary for this purpose; if the jars are over-charged, they will discharge themselves with a loud report. When they are in the proper state, if you wish to discharge them, nothing is necessary but to lay hold of the chain, which communicates with the outside by means of the discharging rod, and to bring the end of it into contact with the conductor: a strong spark will be elicited, and the jars will be discharged.

If a person, holding the end of the chain, should touch with his finger, either the conductor of the machine, or one of the rods which touch the inside of the jars, he might be killed in consequence of the terrible shock he would experience. If a flask indeed, 5 or 6 inches in diameter, strongly charged, give by its discharge a violent shock in the arm and breast, we may form some notion of the effect which would be produced by the discharge of 12, 15, 20, 30 or 50 square feet. Electricians therefore ought to be very attentive to themselves, and to the spectators, for fear of some fatal accident.

All philosophers who perform electrical experiments, on a large scale, have at present a similar apparatus, of greater or less size. It is by these means that they fuse metals, which can be reduced even to a calx; that they communicate the magnetic virtue to a needle, or change its poles, or imitate the effects of thunder, and so on, as will be seen hereafter.

EXPERIMENT XV.

To kill an animal by means of electricity.

Affix the chain, which communicates with the outside of the battery, to one of the animal's feet; and then with the discharging rod form a communication between the animal's skull and one of the rods that communicate with the

inside; the animal, if it be even a sheep, or perhaps an ox, will be struck dead.

REMARK.—It has been observed that the flesh of animals killed in this manner, is immediately fit for being eaten; for the shock which kills them is similar to that of lightening, and it is a well known fact that animals killed by lightening pass very speedily to a state of putrefaction. This artificial lightening might therefore be employed to kill those animals which are intended to be immediately used as food: they will be what is called mortified in a minute. But as the operation is dangerous, Dr. Franklin humorously advises philosophers to be on their guard, lest, in attempting to mortify a pullet, they should mortify their own flesh.

EXPERIMENT XVI.

Production of Magnetism by Electricity.

Provide a steel needle, like that of a compass, some inches in length, and place it between two plates of glass, so that its two ends, A and B, shall project a little beyond them. Then make one of its ends A communicate with the conductor of the electric machine, or any one of the transverse rods of the electric battery; charge the battery strongly, and discharge it through the needle by means of the discharging rod, bringing the end of the chain, which communicates with the outside of the jars, to the end B of the needle. All the electric fluid will pass through the needle, entering by the end A and issuing at B; and the needle will then be magnetised in such a manner, that the end A will turn to the north.

When a needle has been magnetised, if the end A be turned towards the north, performing a contrary operation, that is to say, making the electric fluid pass from B to A, the needle will be un-magnetised; and by repeating the same operation it will be magnetised in a contrary

sense; that is, in such a manner that the end B will turn to the north.

It may be readily conceived, that this will depend on the quantity of the electric fluid. If it be less in the second operation than in the first, some small portion of magnetism may remain; if it be much more considerable, the poles may be changed by the first shock.

EXPERIMENT XVII.

To fuse metals by means of electricity.

This experiment is one of the most curious that are performed by electricity. Take an iron wire half a line in diameter, and suspend from it a weight of about 6 pounds; then by means of a battery, consisting of from 16 to 25 jars, make the electric fluid pass along it; the wire will immediately stretch itself, and sometimes will break. But this could not be the case, were it not softened or mollified in some part of its extent.

Another method. Take a piece of very thin gold leaf, and having cut it into a slip of two inches in length, and a line in breadth, put it between two plates of glass, very close to each other; then place these plates in such a manner as to form part of the electric circle of a strong battery, consisting of 50 or 60 jars. The gold leaf will pass through the state of fusion; and what proves it is, that several of its parts will be incorporated with the glass itself.

But, if you place between the glasses and the gold leaf two bits of card, and squeeze the plates of glass closely together, the electric spark made to pass, as above, through the gold leaf in the direction of its length, will reduce it, in a great measure, into that kind of purple powder known, in chemistry, under the name of the *precipitate of Cassius;* because this preparation was first invented or simplified by that chemist. The two cards will be dyed

f the same colour, which may be heightened by repeating ie operation with new bits of gold leaf.

Silver leaf treated in the same manner gives a powder f a beautiful yellow colour.

Copper leaf gives a green powder.

Tin foil gives a white powder.

Platina, treated in this manner, is reduced, after re-eated shocks, to a blackish powder, which when applied porcelain produces a dark olive colour.

In short, we are assured by different chemical proofs, at these calces are exactly the same as those produced longer processes.

For these experiments we are indebted to M. Comus, so lebrated for his industry and address, and who united to e most extraordinary talents in this way, the most pro-und knowledge in different parts of philosophy. A cir-umstantial and truly interesting detail of them may be en in the *Journal de Physique* for the year 1773.

EXPERIMENT XVIII.

hich proves the Identity of Lightening and the Electrical Spark.

On a high insulated place, such as the summit of a wer, fix in a vertical direction an iron rod, terminating a very sharp point. The higher this point is in the nosphere, the better will the experiment succeed. This r must be supported by some base, to insulate it from ery body capable of conducting electricity.

Then wait till a storm takes place, and when a thunder ud passes over the rod, or near it, touch it with an iron d attached to a glass handle. You will not fail to ex-ct sparks from it, sometimes very large, and accom-nied with a loud noise. It will be dangerous however approach too near it; for the rod is sometimes so highly arged with electricity, that the sparks proceed to the

distance of some feet, and make a noise like the report of a pistol. Mr. Richman, professor of mathematics at Petersburg, and member of the Imperial academy of that city, fell a victim, as is well known, to an experiment of this kind; for in a moment of forgetfulness, having approached too near the machine, he was struck dead, and all those effects observed in persons killed by lightening were seen on his body.

This accident has induced some philosophers who study electricity to arrange their machine in such a manner, that it can never become too much charged with electricity. For this purpose, they place at some distance from the rod a piece of sharp pointed metal, which communicates with the floor or the mass of non-electric bodies. This point, when the electricity is moderate, will attract none of it; but when very strong, it will draw it off as we may say, and discharge it insensibly; so that it will accumulate only in such a moderate quantity, as to be incapable of doing mischief. The nearer the point is to the rod, the more it will absorb of the electricity.

By its means it may be known in obscurity whether the cloud be electrified positively or negatively; for in the first case, you will observe at the point a simple luminous star, or very short gerbe; in the second, you will observe a large and beautiful gerbe.

It is customary also to place near the bar a metal ball, suspended by a silk thread; and, at a little farther distance, a bell communicating with the body of the building. The use of this apparatus, is to inform the observer that the bar is electric; for at the moment when it is charged with electricity, it attracts the ball which possesses none, electrifies it, and propels it against the bell; the sound of which announces that the electric cloud has produced its effect. The degree of the electricity also is indicated by the same means; for if it be very strong, the vivacity of

the ringing is proportioned to it, and the observer is warned to be on his guard.

This experiment, without either a tower or a terrace, may be performed in a chamber. Nothing will be necessary but to place in the chimney a bar of iron, insulated by means of silk strings, which keep it firm on every side. The point of this bar must rise some feet above the top of the chimney: 12 or 15 feet, and even less will be sufficient. Every time then that an electric cloud passes over the chimney, the bar will emit signs of electricity, if touched with caution, or by means of a few electric bells arranged near it.

Instead of this apparatus, Father Cotte, an assiduous observer of all meteorological phenomena, places in a transverse direction, between two elevated places, an iron chain, the links of which are furnished with sharp points. The two ends of the chain are supported by silk strings covered with pitch. From the middle of the chain proceeds another, of the same form and size as those used for electric experiments, which is conveyed into the apartment, either through the chimney or the window, by means of silk strings which support it. At the end it ought to be furnished with a metal ball, which will produce sparks much more considerable than the chain itself would do. The multitude of points, with which the chain is covered, furnish such a quantity of electric matter, that the ball must not be touched without great circumspection.

Remark.—This curious experiment, highly interesting to philosophy, was proposed and announced by the celebrated Dr. Franklin, in letters addressed to Mr. Collinson, fellow of the royal society; but it was performed, for the first time, at Marly, by M. Dalibart and M. Raulet the curé of that place, on the 10th of May 1752. It was afterwards exhibited before the king and the whole court.

Since that time it has been repeated by various philosophers, and at present nothing is more common than this electrical apparatus, which shows the identity of the electric fluid and lightening. But it is to America, and to Dr. Franklin in particular, that we are originally indebted for it.

From this discovery we can deduce the explanation of several phenomena; for which no proper cause had been before assigned. Of this kind are those fires often observed during storms, on the top of steeples, at the extremity of the masts and yards of ships, which the ancients distinguished by the names of *Castor* and *Pollux*, and which are known to the moderns under that of the *fire of St. Elmo.* It is nothing else than the electric fluid of the clouds attracted by the points of these steeples, or the iron at the summits of the masts. Cæsar relates, that a great storm having come on while his army was arranged in the order of battle, flames were seen to issue from the points of the soldiers' pikes. This phenomenon has nothing wonderful in it to those acquainted with electricity. The flames observed were the electric fluid, which escaped from these points; the clouds, in all probability, being electrified negatively, which, according to Dr. Franklin, is often the case.

EXPERIMENT XIX.

Which proves the same fact in another manner.—The electric kite.

It is sometimes difficult, if not impracticable, to raise an iron rod to a great height; and therefore another artifice has been devised to deprive the clouds, in some measure, of their electric fluid or lightening. It is by means of the paper kite, a small machine more employed before that time by young persons and school-boys, than by philoso-

phers; but the use made of it by some of the latter has in some measure ennobled it.

Provide a kite, covered with silk, of a pretty large size, such as 5 or 6 feet in length at least; for the larger it is the higher it will rise, on account of the weight of the cord being less, in comparison of the force with which the wind tends to elevate it. Adapt to the head of it a very delicate rod of iron, extending on the one side, along the lower axis of the kite, to the point where the cord is affixed to it, and, on the other, terminating in a sharp point projecting beyond the kite; so that when the machine is at its greatest height it may be nearly vertical, and rise above it about a foot. The cord must be of common pack-thread, with a very flexible copper wire twisted round it, nearly in the same manner as on the lower strings of some musical instruments, but much closer. This is done, because hemp, unless moistened, is a bad conductor of electricity. To the extremity of this rod is attached another of silk, some feet in length, to insulate the kite, when it has reached its greatest height; and near this silk string is connected with the cord of the kite a small tube of tin-plate, about a foot in length and an inch in diameter, for the purpose of drawing sparks from it.

When these arrangements are made, expose the kite to the wind, when you observe a storm approaching, and suffer it to rise to its greatest height: If the silk string be then made fast to some fixed object, and in such a manner that the string shall not be moistened by the rain, you will not fail to observe very often exceedingly strong signs of electricity; and sometimes so powerful that it would be dangerous to touch the string or tube without the utmost caution.

For this purpose, affix to the end of a glass tube, or a large stick of Spanish wax of about a foot long, a piece of iron some inches in length, having a small metal chain

hanging down from it to the earth. Without this precaution, weak sparks only would be elicited, because the piece of iron being itself insulated, would on the first touch be electrified like the cord of the kite.

M. de Romas, the first person in Europe who employed this method of drawing electricity from the clouds, caused a kite 7½ feet in length, and 3 in breadth, at its widest diameter, to rise to the perpendicular height of 550 feet, and produced by it the most extraordinary effects. Having imprudently touched the tube of tin-plate with his finger, he received a violent shock; but happily the electricity had not nearly acquired its utmost strength; for the storm increasing, some time after he felt, at the distance of more than three feet from the cord, an impression similar to that made by a spider's web; he then touched the tube of tin-plate with the discharging rod, and extracted a spark of an inch in length and three lines in diameter. The electricity then increasing in a very great degree, at the distance of more than a foot he extracted a spark three inches in length and three lines in diameter, the snapping of which was heard at the distance of 200 paces.

But what was most remarkable in this experiment is, that while the electricity was nearly at its highest degree, three straws, one of them a foot in length, stood upright in consequence of the attraction of the tin-plate tube, and balanced themselves for some time between it and the earth, always turning round, till one of them at length rose to the tube, and produced an explosion in three claps which were heard in the middle of the town of Nerac, the experiment having been performed in the suburbs. The spark which accompanied this explosion was seen by the spectators like a spindle of fire, 8 inches in length and 4 or 5 lines in diameter. The straw which had occasioned this spark at last moved along the string of the kite, sometimes receding from it, and sometimes approaching it, and

roduced a very loud snapping when it came near it. me of the spectators followed it with their eyes, to the stance of more than 50 toises.

Farther details respecting this experiment, no less interesting than curious, may be seen in the *Mémoires des vans Etrangers*, published by the Royal Academy of iences, vol. II. It was followed by a great many others the same philosopher, which prove that, even during lm weather, a kite of this kind is sometimes so highly ectrified, as to make the cord to sparkle, and to give olent shocks to those who inadvertently touch it.

We have already said that M. de Romas was the first rson in Europe who made this curious experiment; but had been made some months before in Pennsylvania by . Franklin; for he sent an account of it to Mr. Collin-, his correspondent at London, in the month of Octoer, 1752. This discovery however was not known in nce till a long time after, and M. de Romas even anpced it enigmatically to the Academy of Sciences, about middle of the same year. Thus, while we adjudge the t merit of the invention to Dr. Franklin, we cannot help nowledging that M. de Romas concurred in this respect h the celebrated philosopher in Philadelphia.

EXPERIMENT XX.

The House struck by Lightening.

r. Lind is the author of this experiment, which serves rove the difference between the effects of the explosion hunder when received on a blunt end or ball, or on the p point of an uninterrupted conductor. It displays in fullest light the advantage of good conductors for preing houses from lightening.

B, pl. 8, fig. 43, is the model of a small house, of which the summit of the roof; AD is a wall in which is formed square hole, GFHE, destined to receive a square board;

in this board is placed diagonally an iron rod, which according to the position of the board can be disposed in the direction FE or GH, as seen in the figure. LG is an iron rod terminating in a ball L, which ends at the point G. From H to I is another rod of the same kind, the end of which I terminates in a chain of a length proper for the purpose intended.

When this arrangement has been made, place the board in such a manner that the rod, sunk in it, may be in the direction FE; leaving an interruption from G to H. Then make the chain pass round the body of a jar, like those used for an electric battery, and charge the jar as highly as possible. Then affix to one of the legs of the discharging rod, furnished with a glass handle, the chain of the conductor, and with the other leg of the rod touch the ball L, which rises above the roof of the house, and the rod GC. An electric circle being thus formed, a strong explosion will ensue, and the board FGHE will be thrown from its place on account of the jump which the electric matter must make from G to H, to reach the conductor, which is interrupted in that place.

But, instead of a rod terminating in a ball L, substitute a rod ending in a sharp point, and place the board FGHE in such a manner, that the small rod EF may be in the direction GH; if you then repeat the same operation as before, the electricity will silently pass along the rod LGHI, without displacing any thing.

This is an exact representation of what takes place when a building is struck by lightening. The top of the building receives the shock, and the lightening follows the first metallic conductor it finds, without doing it any damage, provided it be of a sufficient size; but if this conductor be any where interrupted, it makes an explosion, and blows to pieces the walls, the wainscotting, &c, till it finds a new conductor. At every interruption a new explosion takes

place, to the great danger of those who are in the neighbourhood; for as the body of a man is a pretty good conductor of electricity, on account of the fluids with which it abounds, it attacks him in preference, and infallibly destroys him.

But if the rod, elevated above the house, terminates in a sharp point, and if the conductor is not interrupted, nothing of this kind will take place. There may be some slight explosion at the point of the bar; but the electric fluid of lightening thence follows the conductor to its extremity, which is sunk in the earth to a depth sufficient to reach moisture.

M. Sigaud de la Fond, professor of natural philosophy, rendered this experiment still more sensible, by the disposition he gave to the small house. It was such that the electric explosion blew up the roof, and separated the walls.

EXPERIMENT XXI.

The Ship struck by or preserved from Lightening.

This experiment, in some respects, is merely a variation of the preceding. We have introduced it however, because it is no less amusing, and is equally calculated to prove the utility of uninterrupted metallic conductors, for preventing damage by lightening.

In the middle of a small boat, representing the hull of a vessel, raise a tube about eight inches in height, and half an inch in diameter, to represent the main-mast. Fill this tube with water; and, having closed both its extremities with two pieces of cork, introduce through them two pieces of iron wire, so that the ends of them shall be at the distance of half an inch from each other, in the inside. The lower piece of wire must be immersed in the water on which the vessel floats, and the upper one must terminate, without the tube, in a small knob.

Now, if a communication be established between the exterior surface of an electric battery and the lower wire, and if the end of the iron chain which is connected with the inside of the battery be applied to the end of the upper wire, the explosion of the electric matter, passing from the end of one wire to that of the other in the tube, will be such, even if a small part only of the chain be employed, that it will shatter the tube to pieces; and the bottom of the vessel being pierced, it will sink. Such is the manner nearly in which the main-mast of a ship is shivered by lightening, so that the vessel is in danger of being lost.

But if, instead of two wires, one only be made to pass through the two pieces of cork and the water with which the tube is filled, and if the same communication be established with the electric battery, the charge of sixty-four jars may be transmitted through the tube, without doing it any injury. Sometimes however the force of the electric matter, or of this small flash or artificial lightening, will be so great, as to destroy the metallic wire.

This experiment was invented by Mr. Edward Nairne, and might easily be adapted to represent, in a manner more agreeable to reality, the phenomena of a vessel struck by lightening; but we have chosen rather to describe it as given in the *Philosophical Transactions* for the year 1773. It clearly shows how dangerous the interruption of metallic conductors is, and how the smallest conductor, if properly continued, will carry off the electric fluid.

GENERAL REMARK.

On the analogy between lightening and the electric fluid. The means of securing houses from the effects of lightening.

Though the identity of lightening and electricity is sufficiently proved by the preceding experiments; to establish it more completely, we shall mention some of the phe-

omena most commonly observed in the progress of lightning, when it falls on a house or any other object.

The first of these phenomena, or what takes place most equently, is, that the lightening runs along metallic odies, wherever it meets with them in its way. For want f metallic bodies, it explodes, or attaches itself to moist odies, or to animals, which are composed almost entirely f fluids. Hence it is often observed, when the lightening lls on steeples, that from the weather-cock or cross on e summit, which receives the first shock, it runs along e iron work, proceeding thence to the roof or to the inde of the building, and there explodes; for as it no nger meets with any thing besides wood or stone, which e bad conductors, it cannot conveniently pursue its urse; it therefore often strikes men who are in the eeple, in consequence of a bad custom which prevails of nging the bells on such occasions. Sometimes it falls on e bell and follows the rope to its extremity; and if the pe at that moment is held by a man, he seldom escapes struction; for being a better conductor than hemp, the htening seems to give him a fatal preference.

It very often happens that the lightening melts the lead the cross, which it strikes rather than other bodies, which e worse conductors.

We may thence explain also, why it has happened that an with a sword by his side has been struck by lightening, without sustaining any hurt, and that the point of the ord has been found melted in the scabbard; it is because electric fluid preferred passing through the sword, ening at the hilt and issuing at the extremity; and as this emity terminates in a sharp point, it found it more pact, and reduced it to a state of fusion. This effect be imitated, by causing a large quantity of the elec- matter to pass through a sharp-pointed wire.

When lightening falls on a tree, if there be any animals

beneath, they rarely escape, especially if the tree be of a resinous or oily nature. The reason of this is, that wood is a bad conductor; the lightening therefore abandons it if there be a better conductor, such as an animal, in the neighbourhood. Hence it happens that the walnut tree is reckoned to be particularly dangerous: its oily sap renders it a worse conductor of electricity than any other.

But it is when lightening falls on a house that its predilection for metallic bodies principally appears. Almost all the accounts of the effects of lightening agree, in representing the electric matter as preferring to run along the wires fixed to the bells, or the metallic edges of cornices, or looking-glasses, or pictures, &c, exploded every time that this route, which it finds most commodious, is interrupted. It has been seen to pass, in this manner, through several apartments, and even through several stories. This route indeed is so well established by the observations which have been made, that there is every reason to believe, that if these metallic conductors had been wanting, or had been insufficient, it would have occasioned great damage.

One of the best related, and most remarkable accounts of such events, is that of the lightening which struck the hotel occupied by Lord Tilney at Naples, on the 20th of March 1773. We are indebted for it to Sir William Hamilton, who was present in the apartment, through which the lightening passed, together with M. de Saussure, professor of Natural History at Geneva, and they both soon after examined the whole hotel with the utmost care, in order to trace out the progress of the meteor. The circumstances of this event were as follows.

The apartments of Lord Tilney, which consisted of nine rooms on a floor, were decorated with great elegance, like most of those belonging to persons of rank in that country. A very large cornice went round all the rooms, and this

ornice was gilt in the Italian manner; that is to say coated ith tin-foil, covered with a yellow varnish, in imitation f gold. From this cornice proceeded a great number of lat-bands, which served as frames to the tapestry, and hich were gilt in the same manner, as well as the borders the pannels of the wainscotting, the frames of the pictures, and the mirrors, the door-posts, &c. The apartments ove were ornamented in the same style. This hotel had profusion of such ornaments; and it is to be observed at all the rooms communicated with each other by means the bell-wires, which, for the sake of convenience, were ry numerous.

Lord Tilney had a party to dinner, and Sir William milton says, that on this occasion there were in the hotel wards of 400 persons, including the domestics. A loud ip of thunder was heard, and in an instant the whole artment, where the company were assembled, seemed be on fire. Every one thought himself struck by the htening, and the terror and confusion which this cirmstance produced may be easily conceived. No person wever was either killed or wounded; and this no doubt s owing to the prodigious quantity of metal conductors, ich enabled the lightening to pass through them.

Sir William Hamilton and M. de Saussure having exined, soon after and next day, the different apartments, erved that the greater part of the extensive cornices re damaged, and black in a number of places, particuly at the corners, and where the bell-wires passed through m; the gilt varnish was detached in many parts, and own down in the form of powder; in some other places cords of the bells were burnt. In one room where two ntings were suspended, one above the other, between cornice and the door, the lightening had passed from cornice to the gilding of the frame of the picture imliately below; then to that of the second picture, and

thence to the frame of the door, and its course was marked on the wall, which was whitened according to the custom of the country, by the impressions of the smoke. In another room, the lightening had also passed from the cornice to the frame of the picture, which was in contact with it, and thence to the interior border of the frame of the door, making an explosion each time; it had then descended along the frame of the door, and had split part of a small socle, at which the mouldings terminated. The same phenomena nearly had taken place in the upper story.

It may be seen, by this description, that the lightening had preferred passing through all these metallic materials; and there can be no doubt that it was owing to the great profusion of gilding, and to the wires of the bells, that some of the persons present escaped being killed.

The predilection which the electric matter, or lightening, shows for metallic conductors, induced Dr. Franklin, about the year 1752, to propose, at Philadelphia, a new method of preserving edifices from this destructive meteor. It consists in placing on the tops of the houses an iron rod, terminating in a point, and continued downwards by several more rods joined together. The lowest rod ought to be sunk in the earth to a sufficient depth to meet with moisture, which, being a good conductor, will convey off the electric matter, by transmitting it to the whole mass in the earth. In regard to the size of the rod, Dr. Franklin observes that three or four lines in diameter will be sufficient.

In the year 1755, a great many houses in North America, and particularly in Pennsylvania, Maryland, and Virginia, where thunder is very common, and often falls on buildings, were furnished with conductors of this kind. It is allowed that several of these houses were struck by lightening; but the circumstances always observed in America,

re as follow: 1st, that the damage done to these houses is less: 2d, that when they were struck, the lightening, stead of occasioning the same havoc as in others, passed f by the conductors, leaving only a slight impression in e neighbouring parts. In these cases the point of the nductor was, for the most part, found to have been sed.

The object of these rods is not indeed, as was at first pposed in Europe, to deprive an immense cloud of its ectricity; but to furnish a conductor to that electric itter, when by an accident, which cannot always be oided, a cloud highly charged with electricity has fallen an edifice.

This expedient however found powerful opponents, pecially in France. One of the most conspicuous was e celebrated abbé Nollet, the rival of Dr. Franklin in the eory of electricity; but it must be allowed that nothing ald be weaker than the arms with which the French philopher combated the American. They were mere astions, unsupported by any proofs, or rather contrary to result of experiments. According to Nollet, these inted rods of iron are more calculated to attract the lightng than to preserve from it; and it is not a rational prot for a philosopher, says he, to exhaust a stormy cloud the electric matter it contains. To answer these asserns, it is sufficient to be acquainted with the effects of htening. They prove in the most evident manner, that he places where it fell had been furnished with good nductors, no explosion would have taken place. Bees, it is not true that a sharp-pointed rod attracts the etricity of a storm-cloud; on the contrary, if a sharp int be presented to a flake of cotton suspended from the nductor of the electric machine, it immediately repels Is it therefore better to wait till a storm-cloud, charged h electricity, and driven by the wind against a building,

shall explode and pour into it a torrent of the electric fluid, than to draw it off by degrees, so that when it approaches the edifice it shall be entirely deprived of it? In regard to the impossibility of freeing a cloud entirely from its electric matter, it is needless to make many observations; as all that is meant is merely to supply the electric matter, poured forth from a storm cloud, with the easy means of escaping. But when it is considered, that every time almost that lightening has fallen in any place, without doing damage, it has followed conductors as small as a bell-wire, or gilding, &c, and that it has never exploded but when its course was interrupted, there can be no doubt that a rod, half an inch or an inch in diameter, would afford a passage to all the electric fluid that could be produced by the largest cloud.

Sharp-pointed conductors, considered as preservatives against the effects of lightening, were opposed in England by the noted electrician Wilson, on the following occasion. The method proposed by Dr. Franklin, for preventing the effects of lightening, having excited the attention of the government in 1772, the Royal Society of London were consulted on the means of securing from this destructive agent the new powder magazines at Purfleet. The society having appointed Mr. Cavendish, Dr. Watson, Dr. Franklin, Mr. Wilson, and Mr. Robertson to examine this subject; four of these gentlemen were of opinion, that the magazines should be furnished with sharp-pointed conductors. Mr. Wilson alone maintained that the points of the conductors ought to be blunt, and he refused to sign the report. It may be easily seen that Mr. Wilson's motive was an apprehension that sharp-pointed conductors might attract the electric fluid at too great a distance. Dr. Franklin, in a paper written on purpose, which contains an account of new and ingenious experiments, endeavoured to make him change his opinion; but did not succeed.

?he magazines of Purfleet however were furnished with onductors according to the idea of Dr. Franklin and the ther three commissioners.

The sequel of this business gave rise to the most ex-ordinary transactions that ever occurred in the Royal ciety.

EXPERIMENT XXII.

Of some amusements founded on electric Repulsion and Attraction: The Electric Spider, &c.

Cut a small bit of cork, or of the pith of the elder tree, to the form of a spider, and fix to it six or eight cotton linen threads, a few lines in length. Suspend this small gure from a hook by a silk thread, and place on one side it, and at the same height, the knob of a small jar sitively charged, and on the other that of a jar nega-ively charged, or merely a similar knob not electrified, d communicating with the general mass of non-electric dies. You will then see this figure first attracted to-rds the electrified knob, and then repelled by it; and as filaments of the threads will mutually repel each other, spider will appear as if at work, and extending its legs lay hold of the second knob. But it will have no sooner ached it, than it will seem to fly from it; for when de-ived of its electricity by the touch, it will be attracted the first knob, from which it will be afterwards repel-d; and this play will continue as long as there is any ctricity in the jar.

A common conductor charged with electricity will ply the place of the electrified jar; and, instead of electrified knob, the finger may be employed. The der, after having touched the conductor, will appear throw itself on the finger, as if to seize it, and will em-ce it with its legs.

EXPERIMENT XXIII.

The Electric Wheel and Turnspit.

Construct a wheel consisting of eight or ten glass radii, implanted in a common centre, about six or eight inches in length, and each furnished at the extremity with a ball of lead.

This wheel must be placed, in perfect equilibrium, on a small vertical axis, which turns in a piece of glass, so that the slightest impulse can put it in motion. The stand, by which it is supported, must be susceptible of being insulated.

Then provide two jars, one charged positively and the other negatively; and, having insulated the above wheel, place the two jars one on each side of it, so that the balls shall pass at the distance of a quarter of an inch from the knob of each jar.

It may be easily conceived, that if this small machine be in perfect equilibrium, when one of the balls approaches one of the knobs, that for example which belongs to the flask charged positively, it will be attracted by it, and the machine will tend to turn round; but the ball, by passing near to that knob, will be electrified positively, and consequently will be immediately repelled.

The same thing will take place in regard to the flask which is charged negatively: the non-electrified ball will be attracted by it, and in passing near it will be electrified negatively; it will therefore be repelled, as soon as it has passed it.

As the same thing takes place in regard to all the other balls, the result will be a circular motion, which will be accelerated more and more, and will continue as long as the two jars are in a state of electricity. But they may be easily kept in motion, by making the knob of a jar strongly charged touch that of one of them, and the knob of the

other the side of the same jar: by these means the one will be charged positively, and the other negatively.

When the electricity is very strong, and the machine is well constructed and in equilibrio, it acquires a motion capable of turning a weight of several pounds placed on its vertical axis.

The electricians of Philadelphia employed this apparatus to turn a spit, when a party of them met to amuse themselves with philosophical experiments. Being persuaded, no doubt, that Reason must sometimes throw itself into the arms of Folly, they assembled on the banks of the Skuylkill, a river which runs past Philadelphia, and having killed a turkey, by the electric shock, they placed it on a spit adapted to an electrical jack, and roasted it at a fire kindled by the electric spark; they then drank to the health of the European and American philosophers who cultivated electricity, not amidst the noise of musketry, but of electric batteries discharged at each toast. Dr. Franklin, the first of the philosophical electricians, calls this an *electrical feast*.

EXPERIMENT XXIV.

The Electric Alarum and Electric Harpsichord.

Suspend from the conductor of an electric machine three bells, at the distance of about an inch from each other; but the outer ones must be suspended by threads which transmit the electric fluid, and that in the middle by a silk thread, or other electric substance. The bell in the middle must communicate, at the same time, with the floor, by means of a small chain or metallic wire.

At equal distances, between each of these three bells, suspend by silk threads two small balls of metal, in such a manner, that when pulled a little to the right or left, they shall strike against the bells.

If the conductor be now electrified, you will immedi-

ately see these small clappers put themselves in motion, and strike the bells alternately, which will form a small alarum, and if the electric apparatus be concealed, it will be difficult for those present to discover the cause of it.

The cause however of this continued play may be easily discovered; for, by the construction of the apparatus, the two lateral or outer bells are electrified, as soon as the electric machine is put in motion. The small balls suspended between them and that in the middle will therefore be attracted by these bells; but as soon as they touch them they will be repelled, being electrified in the same manner as they are; they will then be carried towards the middle bell, which having a communication with the floor, will immediately deprive them of their electricity. They must therefore fall back towards the electrified bells, which will attract them again; and this play will continue as long as the electric machine is kept in action.

REMARK.—On this principle, an instrument, called the *electrical harpsichord*, has been invented. The following is a short account of this ingenious machine, for which we are indebted to Father de la Borde, a Jesuit, who gave a description of it in a small work published in 1759.

Suppose an iron rod, supported by silk strings, and furnished with two rows of bells, each two of which are capable of emitting the same sound, because two will be required for each tone. One of these bells must be suspended from the rod by a wire, so that when it is electrified the bell may be electrified also. The other must be suspended by a silk string; and between each pair of bells a small ball of steel must be suspended by the same means.

The bell suspended from the bar at the top, by the silk string, is furnished with a wire which proceeds downwards, and is fixed by another silk string. To its lower extremity is fastened a small lever, which in its usual position rests

n another insulated bar, communicating as well as the ther with the conductor of an electrical machine.

In the last place, below this second bar is a harpsichord, o disposed, that when one of its keys is touched, the other xtremity of it raises up the corresponding lever; this inercepts the communication of the bell with the electrified onductor, and establishes a communication with the geeral mass of the earth.

After this description, it may be easily conceived, that one of the keys be touched, while the electric machine in motion, one of the bells being electrified, the steel all will immediately advance towards the other, and, eing electrified by it, will be repelled towards the first, hich will deprive it of its electricity, and therefore it will eturn to the other. This motion will take place indeed ith great rapidity, and the result will be an undulating ound resembling the vibrations of an organ. When the ever falls down, the two bells are equally electrified, and a moment the steel ball stops.

Father de la Borde, having constructed this machine, ould by practice perform on it, with a considerable deree of correctness, simple airs. But was it of sufficient nportance to be made the subject of a particular treatise, nce neither the science of music nor the theory of elecicity could be much benefited by it?

EXPERIMENT XXV.

he electrical Horses which pursue each other, or the Electrical Horse-race.

With two small iron plates, or two small wires, construct kind of cross, having a piece of copper in the centre, so s to represent two magnetic needles crossing each other t right angles. The ends of these four branches must rminate in a point, and about an inch of the extremities f them, more or less according to the size of the machine,

must be bent back, so as to form somewhat less than a right angle. On these bent ends fix a small bit of light card, and place on each the figures of horses, having their tails turned toward the points. Then arrange the whole on a steel pivot, raised in a perpendicular direction, that the cross with its load may preserve itself in a horizontal direction, and have a very easy rotary motion.

Having then insulated the machine and its plate, if the latter, or the point of steel, be made to communicate with the electrified conductor, you will soon see these four branches of iron assume, as if spontaneously, a rotary motion in a direction contrary to that in which their extremities are bent; so that the four horses will seem to pursue each other in a circular course. And this play will continue as long as the electricity lasts, and even longer, on account of the acquired velocity.

If the experiment be made in the dark, and without the horses, that is to say with the four points alone, you will see pencils of light or electric fire issue from them, which will form a very agreeable spectacle, as the result will be a ring of fire; and this ring may be rendered larger by giving unequal lengths to the branches of the cross.

Several stages of wires, placed in the form of a cross, each stage always decreasing in size, might be constructed, and by these means a luminous pyramid would be formed.

The cause of this apparently spontaneous motion may be easily conceived. It is the impulse of the electric matter, issuing from the points, which meeting with the air, experiences a reaction, and is impelled backwards.

Remark.—Some have pretended to deduce from this experiment a pretty strong objection against the hypothesis of Dr. Franklin; for whether this small machine be electrified either positively or negatively, the motion takes place in the same direction, which has astonished those

ven who are decided Franklinians. To us this objection ppears to have little weight; for in our opinion it might e said, that in the case of negative electricity, the electric uid which is thrown into the points, can be absorbed, ithout communicating to them an impulse, which acts xactly in the same direction as the repulsion experienced y the electric fluid, on issuing from the points when ley are electrified positively.

EXPERIMENT XXVI.

'o cause writing in luminous characters to appear suddenly, by the means of electricity.

This electric amusement is founded on a well known oservation, that if several metallic wires be disposed together, in such a manner that their ends, without being in ontact, shall approach very near to each other, so as to e at the distance of a line, or half a line; if the first be ectrified, while the last has a communication with the ass of non-electric bodies, sparks will continually be nitted between the ends of these wires.

The same thing will take place if the last of these wires rminate in a point; for as it will by these means lose its ectricity, there must be a continual afflux of new matter; id this cannot be the case without causing a spark in ch of the small intervals, that separate the ends of the ires.

This being understood, it may be easily conceived that series of sparks, forming any representation whatever, th some limitations, which will be seen hereafter, might produced, by arranging the ends of the wires along the itlines of any figure. If the last of the wires be then uched by the finger, or, what will be still better, with e exterior furniture of the Leyden flask, there will be stantly formed, in the intervals between these wires, arks representing the contour of the figure.

But, as this would be attended with difficulties, it may be easily executed in the following manner. Cut a leaf of tin-foil into small pieces, of a line or half a line square, or into the form of a rhombus somewhat elongated. Then delineate on paper the letters you intend to represent, and having put a plate of glass, about a line in thickness, on the drawing, cement to the glass the small squares of tin-foil, or the rhombs above described, according to the outlines; taking care that the angles correspond to angles, and that they be at the distance from each other of about half a line, as seen in the delineation of the letter S, pl. 8 fig. 44. Then connect the extremity of one letter with the commencement of the following one, by a small bent metallic plate, terminating on both sides in a sharp point, as seen in the same figure; a small plate of the like kind at the commencement of the first letter, and another from the end of the last, must proceed to the edge of the glass, and beyond it.

Let us now suppose that the first of these small plates has a communication with the electric conductor, and that you touch the second, or vice versa; each angle of the small squares will convey the electric fluid by a spark to its neighbour; and if the experiment be performed in the dark, these two letters will be perceived as if delineated by a series of luminous sparks.

If the last plate communicate with a mass of non-electric bodies, and if the electricity be strong, an explosion will take place between each square, which will render this writing luminous.

REMARK.—But it is to be observed, that all the letters of the alphabet cannot be represented in a manner so simple as the two here given by way of example. Thus, the O cannot be represented by this method, as the electric fluid, instead of going round in a circle, would proceed from the first to the last square. The A also would remain

truncated at its upper part, as the electric matter would pass through it. A particular artifice therefore is necessary to obviate this inconvenience, which occurs in regard to a great many other letters, such as E, F, H, &c.

This artifice consists in delineating one half of the letter on one side of the glass, and the other half on the other, and in forming a communication between them by a small metallic band, which, proceeding from the upper to the lower side of the glass, may convey the electric matter from the last square of the first half of the o (pl. 8 fig. 45) for example, to the first square of the second half of the same letter; and then uniting, by a similar band, the last square of that second half with the first square of the following letter. If fig. 45 be carefully examined, the mechanism of this amusement will be easily comprehended. The letters, or parts of letters, represented on the upper side of the glass, must be strongly shaded, and those on the lower lightly. As the propagation of the electric fluid is instantaneous, no inconvenience can arise from this method of transmission.

It may be readily seen that such an artifice, in the times of superstition, might have been employed to terrify the ignorant. If a number of people, assembled in a dark place, should see, after a clap of thunder, a luminous writing on the wall, containing a pretended decision of the deity, what would they not be capable of doing? and with what terror would a man be struck, who on waking should see written on the glass, *This day thou shalt die?*

EXPERIMENT XXVII.

Electric Fire-Works.

We shall here describe a new kind of spectacle. We will not absolutely warrant its success, but we are inclined to think that our idea is susceptible of being carried into execution.

An exhibition of fire-works is generally composed of a fixed decoration, representing an edifice, suited to the subject, and of various moveable pieces of fire; such as rockets, gerbes, cascades, fixed or revolving suns, &c; and all these pieces, in our opinion, may be represented by merely electric fire.

Let us first assume, by way of example, a decoration of architecture, which is illuminated by a series of lamps, disposed in such a manner, as to trace out its principal parts. Now, might not a series of points, rendered luminous by electricity, be substituted instead of these lamps? The preceding experiment will furnish us with the means of accomplishing this end; for since letters, the figures of which are much more complex, may be rendered apparent by a series of similar points, lines, the greater part of which are straight and parallel or perpendicular to each other, may be represented with much more ease, by attending to the directions given in that experiment. The following however is another method.

On a piece of very dry and well planed resinous wood, trace out the design of your decoration, and mark by points the places where lamps would be suspended, were it to be illuminated; then place at each of these points a piece of iron wire, one or two lines in length, and terminating on the outside in a very delicate sharp point; and form a communication between all these wires by a long piece of wire connected with them. If the electric matter be then excited in a powerful manner, there is no doubt that each of these points will emit in the dark a small luminous gerbe, which will trace out the design of your architectural decoration; for it is well known that a bar of iron, when strongly electrified, throws out in the dark from all its angles large luminous gerbes, which are sometimes several inches in length.

Nothing is easier than to represent a gerbe of fire: a

roup of iron wires, terminating in a point, will produce n assemblage of small gerbes, which together will form ne of a considerable size.

If a fixed sun is to be represented, it may be done by eans of ten or twelve points disposed in the form of radii, the extremity of a wire which terminates in a button: d if twelve points be arranged in a proper manner, they y form a star by the emanation of the electric fluid: thing will be necessary but to dispose them in the same nner as rockets are in common fire works, to represent e same thing.

If several pieces of iron wire, terminating in a point, d having a communication with a common handle, be anged in a semicircular form, in a direction inclined to horizon, they will represent a cascade, by the electric rbes which issue from their points.

If the figure of a revolving sun be required; you must struct a cross similar to that described in the 25th exriment; but instead of making it turn round on a verti- axis, it must be brought into perfect equilibrium on a izontal one. The luminous gerbes which issue from bent points will form a circle of fire, if the motion be id, or something that has a near resemblance to a sun. What may give to this exhibition an air of reality, is t it is possible to accompany it with the noise of an tric battery, which will excite the idea of marroons saucissons, a discharge of which accompanies in ge- al other fire-works, if not continually, at least at certain rvals. This might be done by means of small electric eries, discharged partially and successively.

This, as already said, is merely an idea, which has need eing subjected to experiment; but in our opinion an nious artist might turn it to advantage. It may easily onceived, that the electricity in this case ought to be ng; but what could not be done by one electric ma-

chine might be performed in all probability by two, or three, or four.

EXPERIMENT XXVIII.

On the Electricity of Silk.

We shall here present the reader with a few more singular experiments made by Mr. Symmer, who published them in the *Philosophical Transactions* for the year 1759.

1st. During exceedingly dry, cold weather, when a north or north-east wind prevails, take two new silk stockings, the one black and the other white, and after having heated them well, put them on the same leg: the action of putting them on will itself electrify them. If you then pull them off, one within the other, making them both glide at the same time on the leg, they will be found so much electrified, that they will adhere to each other with a greater or less force. Mr. Symmer once saw them support, in this manner, a weight which was equal at least to sixty times that of one of them.

2d. If you draw the one from within the other, pulling one by the heel and the other by the upper end, they will still remain electrified, and you will be astonished to see each of them swell in such a manner as to represent the volume of the leg.

3d. If one of these stockings be presented to the other at some distance, you will see them rush towards each other, become flat, and adhere with a force of several ounces.

4th. But, if the experiment be performed with two pairs of stockings, combined in the same manner, the one white and the other black, on presenting the white stocking to the white, and the black to the black, they will mutually repel each other. If the black be then presented to the white, they will attract each other, and become united, or will tend to unite as in the third experiment.

5th. The Leyden flask may be charged by these stockings.

It appears thence to result, that silk rubbed against silk is capable of electrifying; but for this purpose a preparation must be given to one of the pieces: for two white or two black stockings, placed one within the other, cannot electrify. But it is not the black as black, opposed to the white as white, which produces this effect. The abbé Nollet has shown, that the preparation here alluded to is the operation of galling, which precedes that of dying black; for two white ribbons, one of which only is galled, if rubbed against each other properly, will produce the same phenomena of adhesion, attraction and repulsion. There can be no doubt that the case is the same in regard to stockings.

The partisans of the Franklinian doctrine, respecting electricity, will not find it difficult to explain the other phenomena which have been mentioned. Each stocking is electrified in a different manner, one positively and the other negatively; it appears that it is the white which is electrified positively, or in the manner of glass. The swelling up, observed in each of the insulated stockings, is only the effect of repulsion between the bodies similarly electrified; for all the parts of the same stocking have received the same electricity. For the like reason, two stockings of the same colour necessarily repel each other.

But, if a black stocking be presented to a white one, as their electricities are different, these two bodies will attract each other; this phenomenon is well known, and if not general, does not fail to take place between two bodies electrified, one positively the other negatively, or the one in the manner of glass, and the other in that of sulphur.

A very remarkable phenomenon here is, that two bodies, the one electrified positively, and the other negatively, according to the language of the Franklinians, may be

applied to each other, without their electricity being destroyed. Mr. Symmer remarks this with some astonishment; and hence he was induced to deviate from the Franklinian doctrine in assigning reasons for it, which, as the abbé Nollet observes, approach near to the explanation of the latter.

It has since been remarked, that the surfaces of two bodies, one of which is electrified positively, and the other negatively, may be applied to each other, without their electricity being destroyed. This is the principle of the electrophorus, a new electric instrument, invented a few years ago. Nay more, these two surfaces applied in this manner retain their electricity much longer: but it does not manifest itself when they are separated. Electricity is a mine, which, the more it is searched, presents new phenomena difficult to be explained. How this is to be explained, according to the Franklinian theory, we do not know; and, though attached to the science, we shall not attempt it.

EXPERIMENT XXIX.

Which proves that electricity accelerates the course of fluids.

Provide a capillary tube; or a tube terminating in an aperture so narrow, that the water which runs through it can issue only drop by drop. If this water be electrified, you will immediately see it run out in a continued stream.

REMARK.

On the consequences of this experiment, and the cures performed, or said to be performed, by electricity.

It is probable that it was this experiment which gave rise to the application of electricity to medicine; for it was natural to reason in this manner; as electricity accelerates the course of fluids, it is probable that it will

ccelerate that of the blood, and of the nervous fluid in nimals. But there are certain diseases which appear to e merely the consequence of an accumulation of the ervous fluid, such as the palsy, and different maladies deending on the same cause; as deafness, blindness, &c: onsequently, electricity, by accelerating either the course f the blood, or that of the nervous fluid, may remove hat accumulation, and so will produce a cure of the isease.

Some physicians therefore began to electrify patients atacked by the palsy; and it must be allowed, as we have he testimony of persons free from every kind of suspicion, uch as M. Jallabert of Geneva, and others, that the atempt was attended with some success. It is certain that his celebrated professor, and citizen of Geneva, if he did ot cure radically, at least greatly relieved a person of the ame of Noguez, afflicted with a paralytic disorder. This an, who was incapable of raising up his arm, after being lectrified three months, was able to raise up a large ammer.

This cure, which was published in some of the journals, ade a considerable noise, as may be well supposed; and multitude of electricians, in various parts of Europe, ndertook the cure of paralytics, the dumb, the blind, &c. We have a collection, in three volumes, by M. Sauvages, ot of these cures, for there are few to which that appellaion belongs; but of the progress of this application of lectricity. There were some however very well estalished, such in particular is that of a young man of Colchester, to whom Mr. Wilson restored the use of his ye-sight, which he had lost after a violent fever. In egard to the greater part of the rest, the application was f no effect.

It cannot however be denied, that on the first application f the electricity, the patients in general experienced some

relief. Paralytics felt, in the palsied part, a kind of heat and pricking, which seemed to announce the return of sensation; the blind sometimes saw sparks of light: but in general nothing farther took place, and these beginnings, which seemed to promise the greatest success, were not followed by happy consequences.

Some Italian philosophers have asserted something more marvellous. About the year 1750 they announced, at Padua, that electricity exalted and attenuated odours to such a degree, that they passed through glass; that purgative drugs put into a vessel carefully, and hermetically sealed, produced their effect on the person who held the vessel in his hand, while it was electrified. This no doubt would have been a noble discovery in medicine: but unfortunately this pretended discovery, announced with great solemnity to all Europe, vanished entirely before the enlightened eyes of the abbé Nollet, who undertook a journey to Italy to examine it. He found, at least, that there was precipitation and misconception in all these fine assertions, which could not be realized in his presence. Having repeated the experiment himself several times, in his closet, he never found that the most penetrating odour passed through the pores of a glass vessel, when properly closed, whether electrified or not electrified; and the case was the same with the purgative emanations of cassia and rhubarb.

M. le Roy, one of the French philosophers, who cultivated this branch of philosophy with the greatest care, was induced to try the effects of electricity on some of his patients; the first of whom had been afflicted with a hemiplegia for three years; another with a gutta serena; and a third with deafness. The electric matter conveyed several times through the palsied parts of the first, seemed in the commencement to revive sensation; the patient perspired a great deal, an effect which could not be pro-

ed by all the medicines before administered to him. er being electrified four or five months, sensation and power of motion returned to the palsied fingers, and patient could lay hold of a glass, and convey it to his ith, he could even raise a weight of 40 or 50 pounds; this commencement of a cure was all that could be ted; and as the patient received no additional benefit a a continuation of the same treatment, for four months e, it was laid aside as entirely useless.

I. le Roy received as little satisfaction in regard to his l patient, though in order to free the optic nerve from bstruction, he had invented an apparatus, by means of lh he gave him gentle shocks through the head. The ent, at the moment of the electric explosion through read, perceived a flash, but after the electricity had f applied some months, M. le Roy became tired, as re, of administering a useless remedy.

he patients labouring under deafness were not more inate. M. le Roy directed the electric fluid from one o the other. At each shock a kind of noise was heard e head, which one of them compared to all the petards Grêve. But the auditory nerves were not cleared, was the deafness removed. An account of the treat- of these patients may be seen in the Memoirs of the emy of Sciences, for the year 1755.

e have read, somewhere in the Philosophical Trans- ns, of an intermittent fever being cured by electricity. is not impossible; as the electricity, by accelerating iotion of the fluids, might act as a tonic.

me years ago, the abbé Sans, canon of Perpignan, inced at Paris several cures which had been per- d in his country by electricity. He published them in ticular work, with various certificates annexed; but erations on M. de la Condamine, attacked with total sibility in one half of his body, and total deafness, were

attended with no effect. These infirmities indeed had taken root for several years, and therefore it would have been unjust to require success in any attempt made to remove them. But we never heard that this electrician had ever much success at Paris.

To conclude, it appears to us that too great hopes were at first conceived in regard to the application of electricity to such diseases; but that it was not entirely without effect, and that in recent cases it might be tried with some hope of success. The rheumatism, according to M. le Roy, seemed to oppose the least resistance to this remedy, which perhaps acted by re-establishing perspiration. He obtained profuse sweats to the greater part of his patients. In short, there can be no doubt that it occasions in the human body an universal orgasm, which under certain circumstances might be critical and advantageous.

EXPERIMENT XXX.

Natural and Animal Electricity.

During cold weather, lay hold of a cat, and draw your hand over her back several times, in a direction contrary to that of the hair; by these means you will often excite very strong sparks, which will emit a snapping noise.

Remark.—This however is not the only animal which exhibits the electric phenomena by friction: even men, under certain circumstances, emit sparks which are absolutely of the same nature. There are few people to whom this circumstance is not known by experience. It is during cold winters, and after being well heated, that they exhibit this phenomenon. On these occasions, if they throw off their shirt in the dark, sparks more or less vivid, and accompanied with a sensible snapping, will issue from it. Some, in consequence of a particular temperament,

more subject to this phenomenon than others. In all bability, these persons are very hairy; for hair, as it roaches the nature of silk, is electric by friction; and ording to every appearance it is the friction of the dry, m linen, against the hair, which is also dry and warm, produces this electricity, and the sparks which acpany it. In combing a person's hair of a morning, in frosty weather, it becomes very elastic, and manifests ng signs of electricity.

'hese luminous appearances were formerly classed ng the phosphoric phenomena; but since the new overies in electricity, there can be no doubt that they ng to the latter.

would have been easy for us to enlarge this part of Philosophical Recreations much more, by introducing it a great number of other curious and surprising exments relating to the theory of electricity; but as we t confine ourselves within narrow limits, we shall cone this part with a list of the principal works to which e who are desirous of obtaining a thorough knowledge ectricity may recur. Of this kind are *Essai sur l'Elecé de M. l'Abbé Nollet*, and in particular a work entitled *erches sur les Causes particulières des Phénomenes iques et sur les Effets nuisibles ou avantageux qu'on en attendre*, Paris 1754, 12mo; and to these may be d *Lettres sur l'Electricité*, 3 vols. 12mo. Though the klinian theory seems, in general, to have many more sans than that of the abbé Nollet, it must be allowed the latter applied to the study of this branch of ce with the greatest success. Besides the above, we refer also to various memoirs of the same author, in h he discusses the theory of Dr. Franklin, published e *Mémoires de l'Academie*, for 1755 and 1760, &c; *Recherches sur les Mouvements de la Matière électrique*, M. *Doutour*, 1760, 12mo. These are the best of the

works in which the theory of the French philosopher is illustrated and defended.

The Franklinian theory was made known for the first time, in France, by a work entitled *Expériences et Observations sur l'Electricité, faites à Philadelphie en Amerique par M. Benjamin Franklin*, Paris, 1756, 12mo; translated from the English. We have since seen an edition of Dr. Franklin's works, in two vols. 4to; the first of which contains all his experiments, and a great many interesting facts in regard to electricity. From these works the reader may soon acquire a sufficient knowledge of the theory of electricity. We ought to add also different memoirs of M. le Roy, one of the principal partisans of Dr. Franklin, published in the *Memoires de l'Académie*, for 1754, &c. A very interesting work also on this subject, is a treatise by Father Beccaria, entitled *Dell' Electricismo naturale è artificiale*, which appeared at Turin in 1759, 4to. It contains experiments which are strongly in favour of the Franklinian theory, and a great many new observations concerning the electricity of the clouds. We must not here omit to mention, that Father Beccaria is one of those philosophers who were most successful in cultivating the science of electricity, and that he discovered a number of new and very extraordinary phenomena. In some of the volumes of the *Philosophical Transactions*, likewise, are a great many curious papers on different electric phenomena, by Mr. Nairne and Mr. Wilson, Drs. Lind, Watson, &c; but it would be too tedious to particularise them.

In the year 1752, a work entitled *Histoire de l'Electricité*, was published in three small vols. duodecimo. The author has collected pretty well every thing that had been done or said in regard to electricity before that period; but intermixed with insipid witticisms and illiberal sarcasms. Since that period however, Dr. Priestley, one of the ablest of the English philosophers, has given a new *History*

of Electricity, which is much better, and more instructive. A French translation of it appeared at Paris in 1771, 3 vols. 12mo. To these we may add the following works: Adams's Essay on Electricity, 8vo. 1787. A complete Treatise on Electricity by Cavallo, 3 vols. 8vo. And a learned work on the subject, in 4to. 1779, by Lord Mahon, now Earl Stanhope.

MATHEMATICAL

AND

PHILOSOPHICAL

RECREATIONS.

PART FOURTEENTH.

Chemistry.

IOSE who are only initiated in chemistry must con- 'e an idea of this science very different from that which ntertained by the vulgar. According to the common s of mankind, chemistry is the chimerical art of trans- ing metals, or at most of producing some extraordinary nomena, rather curious than useful. But in the eyes he philosopher, to whom it is known, it is the most ex- ive and most interesting of all the branches of natural osophy. We may even venture to assert, that it is btful whether the appellation of a great philosopher be given to any person unacquainted with chemistry. at least certain, that though without its assistance we account for some of the phenomena of nature, such as notion of the celestial bodies, the effects of the gravity ie air, &c; yet there are a far greater number which be explained by chemistry alone. Indeed chemistry

is not less extensive than nature itself. Animals, vegetables, and minerals, all fall within its province. It is it that analyses them, combines their principles, examines the phenomena resulting from them; and thus renders us more intimately acquainted with their nature. Hence are deduced a multitude of useful processes; so that it may with truth be said, that many of the arts are nothing else than a continual application of chemistry. Of this kind, are the arts of glass making, dyeing, metallurgy, &c. We may even add, that the most common of the arts, those that are most necessary, are often chemical processes; such, for example, is that of washing; respecting the truth of which the person who practises it entertains no doubt; though still it is an operation which chemistry alone can explain. This explanation consists in the property which fixed alkalies have of rendering fat substances soluble in water, and of forming a soap with them. Those who know that one of the first operations of this art is to soak the linen in a kind of ley, made of wood ashes or vegetable fixed alkali (pot-ash), will readily be convinced of the truth of what we have advanced. In this part of our work we need not adduce any other examples.

Chemistry also, of all the branches of philosophy, exhibits the most singular and most curious phenomena. Who will not be astonished to see iron filings, immersed in a liquid as cold as itself, immediately produce a violent ebullition, and vapours susceptible of inflammation? Can any one, without admiring the operations of nature, see this metal, so solid, afterwards destroyed in some measure by the above fluid, and united with it in such a manner, as to pass with it through the closest filtre? Who will not be filled with wonder, on seeing another limpid liquor suddenly dissolve this union, and cause the iron to fall to the bottom of the vessel, in the form of an impalpable powder? It is needless, and would require too much time,

to enumerate here any more of these phenomena, as we shall hereafter give a particular account of those that are the most remarkable and most interesting. But it will first be necessary to bring the reader acquainted with the principal substances employed as agents in these operations.

ARTICLE I.

Of Salts.

The name *salts*, or *saline matters*, is given to all those bodies which, when immersed in water or exposed to damp air, resolve themselves into liquids: of this we have an example in the well known marine salt, in nitre or saltpetre, in alum, vitriol, tartar, sal ammoniac, &c. When immersed in water, these disappear, and become intimately mixed with the whole liquor. This is what is called *solution* or *dissolution*.

Salts, to be dissolved entirely, require a greater or less quantity of water, according to the nature of them. Marine salt, to be dissolved entirely, requires twice its weight of water; alum, twelve times its weight; selenite, six or seven hundred times, &c.

Though acids, alkalies, and their mixtures, generally speaking, are called saline substances, it is necessary in chemistry to consider them separately, in order to obtain a knowledge of their principal properties.

§ 1. *Of Acids.*

We shall not here say, with the author of the *Dictionnaire de Physique portatif* *, and some of the old chemists,

* According to this author, iron is composed of vitriol, sulphur and earth; fermentation is a movement occasioned by the introduction of acids into alkalies: when alkalies coagulate they form crystals: sulphur is an inflammable mixture composed of fire, oil, water and earth; copper is a compound of sulphur, vitriol, &c.!!

that an acid is formed of long, sharp and cutting particles; for nothing is more destitute of foundation; and by the help of such a definition it would be impossible, in an apothecary's shop, to distinguish an acid from an alkali, or from a neutral salt. The following is a more correct description.

Acids in general have a liquid form, and leave on the tongue an impression of sourness and coldness. They possess also the property of changing the colour of blue vegetable juices to red; and they combine readily with alkalies, earths and metals, with which they form neutral salts.

To try an acid by vegetable colours, take syrop of violets, or blue paper, and pour the liquid acid over it: the violet or blue colour will soon assume a red hue. When any liquid therefore, poured over syrop of violets or blue paper, changes the colour to red, we may be assured that it is an acid, or that an acid predominates in it.

Acids are by modern chemists divided into mineral, vegetable, and animal, according as they are derived from one or the other of these sources.

The old chemists were acquainted with no more than three mineral acids, namely the vitriolic, the nitric, and the marine, so called because obtained from vitriol, nitre, and marine salt. The mineral acids now known are much more numerous. These acids are the sulphuric or vitriolic, the nitric, the muriatic or marine, the carbonic, the boracic, the fluoric, the succinic, the arsenic, the molybdic, and the tungstic.

The vegetable acids are also now pretty numerous. The following are known: the acetic acid, or pure vinegar; the tartareous, extracted from tartar; the gallic, from gall-nuts; the citric, from lemons; the malic, from apples; the benzoic, from flowers of benjamin; the cam-

horic, from camphor oxygenated to acidity; the pyro-
rtareous, the pyroligneous, and the pyromucous.

The three last mentioned, however, have recently been roved to be merely acetic acid, rendered impure by em-yreumatic oil *; and ought therefore to be no longer onsidered as distinct acids.

The following animal acids are known: the phosphoric, r phosphorus and oxygen in union to saturation; the ctic, obtained from milk; the sacoholactic, extracted om sugar of milk; the formic, from ants; the sebacic, om fat; the bombic, from silk-worms; the uric, from e human calculus; the prussic, which is the colouring atter of Prussian blue.

Acids formerly were considered either as simple bodies, various hypotheses were admitted in regard to their igin and composition. It is now however proved by ex-riment, that every acid consists of a peculiar body mbined with oxygen, which is the basis of oxygen gas, d thence has been called *oxygen*, that is the generator acidity. The bodies which enter into union with oxy-n, and form acids, are called the radicals, or bases of e respective acids, which they constitute.

When the bases are perfectly saturated with oxygen, e acids are called perfect acids, and are denoted by the mination *ic*, to distinguish them from the imperfect ids, in which the bases predominate, and to which the mination *ous* is given. Hence we have *nitric* and *rous*, *sulphuric* and *sulphurous* acids, &c.

Some bases can combine with an excess of oxygen; the ids thence resulting are called oxygenated or oxygen-d.

Of the Vitriolic acid.

The vitriolic or sulphuric acid, the most powerful of all,

* See Philosoph. Magazine, vol. 8, p. 40.

is furnished by vitriol either green or blue, or by alum, for vitriol is a salt formed merely by the combination or union of an acid with iron, and copper; alum, in like manner, is the combination of an acid with argillaceous earth; and experience has shown that the acid in these three substances is absolutely the same.

It will be sufficient here to observe, that the acid is extracted by means of fire. These matters are inclosed, with certain precautions, in a retort, and being exposed to a strong fire, the violence of the heat obliges the acid, which is susceptible of being reduced to vapour, to abandon the metal or earth, to which it was united, and to pass over into the receiver in the form of a liquid.

Another method, still more simple, of obtaining the vitriolic acid, is by the combustion of sulphur; for it has this substance for its base, and on that account it is now known by the name of the sulphuric acid.

If sulphur be burnt slowly under a bell glass, the fumes arising from it will be condensed on the interior surface of the vessel, and run down in the form of a liquid, which will be an acid with an excess of base, that is sulphurous acid. In this process, the sulphur, by its combustion, receives oxygen from the atmospheric air, which is a mixture of oxygen gas and azotic gas, and at the same time moisture, which enables it to assume the liquid form.

In the large way of manufacture, the sulphuric acid is obtained by burning sulphur with the addition of a little nitre, in an apartment lined all round with lead, a metal on which that acid exercises little or no action. The floor is covered to some depth with water, and the aperture or door is shut as soon as the materials are inflamed. The nitre is employed to facilitate the combustion. The nitric acid, one of the principles in the nitre, is in a great measure decomposed, and gives up its oxygen to the sulphur, which by this supply, and the oxygen it derives from the

air in the room, becomes acidified. When the combustion is over, and the fumes have had sufficient time to be absorbed by the water in the apartment, the door is opened to admit a fresh supply of air, and to introduce a new charge of sulphur and nitre, which is deflagrated as before. This operation is successively repeated for several weeks, till the water, now mixed with acid, is found by examination to be of a certain specific gravity. The fluid s then distilled or simply boiled, which drives off a portion of the redundant water, and leaves the acid in a concentrated state. When this is properly done, its weight is equal to about double the weight of an equal volume of water.

The vitriolic acid is the most powerful of all, and is able o separate all the others from their combinations with alkalies, earths, and metals. In a subsequent article we hall give some experiments to illustrate this chemical play, which is exceedingly curious, and the cause of a housand singular effects in nature.

Of the Nitrous acid.

Nitre or saltpetre, a substance well known, furnishes he nitric acid. Saltpetre indeed is the result of the union of this acid with a matter to which chemists give the name of *fixed vegetable alkali*, because the ashes of vegetables yield the same substance. They are separated from each other by processes which it is not our object here to decribe; and in this manner is obtained a liquor called *nitrous acid;* from which the *nitric acid* is procured merely by separating, by means of heat applied to it in a proper pparatus, that portion which has not been fully saturated with oxygen. It is lighter, and in general less active than he vitriolic acid. It is commonly of a dark yellow colour; nd when well concentrated, continually emits reddish apours, which seem to circulate in the vessel that con-

tains it. The ratio of its weight to that of water is then as 3 to 2.

The nitrous acid, when in a moderate state of concentration, is called also *aquafortis*. It is the proper solvent of silver and copper. When fully saturated with oxygen, or in the state of *Nitric acid*, it is colourless.

Of the Marine or Muriatic acid.

Marine salt, so generally employed and so well known, is the substance from which the marine acid is extracted; for common salt is a combination of this acid with a substance called by chemists the *fixed mineral alkali*, or *soda*. They are separated from each other by certain processes, and the liquor thence resulting is marine or muriatic acid.

The marine acid has characters and properties, which render it very distinct from the two preceding ones. In its highest state of concentration it is only a little heavier than water, being in the ratio of about 19 to 17. Its colour is a lemon yellow, and its smell approaches to that of saffron.

Remark.—To enter into a particular account of all the mineral acids, would require more room than the nature of this work will admit; and it is the less necessary, as information respecting them may be found in almost every work on chemistry.

Of the Vegetable acids.

The preceding remark must be applied also to this class of acids, as we mean to confine ourselves to the acetous, which is well known. Vinegar may be deprived of its superfluous water in a great many different ways; and in this state its strength is little inferior to that of many of the mineral acids.

The following is a simple method of concentrating it.

xpose vinegar to the severe cold during winter: it will ien in part freeze, and if the ice be removed, the reainder will be vinegar of a much superior quality. By peating this operation several times, you will obtain negar more highly concentrated, as the cold has been ore intense. Artificial cold may be afterwards employed, id in a much greater degree than the greatest cold ever perienced in our climates.

§ II. *Of Alkalies.*

Alkalies are divided into *fixed* and *volatile*. The former ive no smell; the latter have a pungent and penetrating lour. The general properties of pure alkalies are:

1st. That they have a peculiar caustic or burning taste, rmed alkaline.

2d. That they change the blue juices of vegetables een; the yellow infusion of turmeric, brown; and the d infusion of Brazil wood, violet.

3d. That combining with acids they form neutral lts.

When a liquor therefore poured over syrops or insions of the above kind, or upon paper that has been iged with them, changes the colour in the manner deribed, it is alkaline, or an alkali predominates in it.

Alkalies however are seldom pure in the strict sense of e word, being generally combined with carbonic acid, fixed air; and in this state they are termed mild, to dinguish them from caustic or pure alkalies, that is allies which have been freed from the fixed air.

The common method of depriving them of their fixed is by throwing into an alkaline solution, or ley, a quany of quick lime. The lime by its greater affinity for the ed air, seizes on it, and leaves the alkali in a caustic ite: for limestone or chalk is pure lime saturated with ed air, which it gives up when exposed to a strong heat;

and it is then called quicklime. When saturated with the carbonic acid or fixed air, from the alkali, it again becomes mild lime or chalk, and falls to the bottom of the vessel.

Of fixed Alkalies.

There are two kinds of fixed alkali, namely, the mineral or soda; and the vegetable or potash. They are called fixed, because, though exposed to a strong heat, they are not dissipated, but fuse like metals, and like them can endure a red heat. They facilitate the fusion of stones, earth and sand; and for this reason are much used, especially the first, in glass-houses. They are both of extensive use in the arts.

Fixed mineral alkali is obtained from marine salt; for when this salt is deprived of the acid which enters into its composition, the remainder is fixed mineral alkali, but to extract it from this substance requires a tedious and expensive process. The most common method of obtaining it, is to burn certain plants which grow on the sea coast, or are washed on shore by the tide. Of this kind is the plant kali or glass-wort, from which the denomination of alkali is derived, and various other marine plants, such as *varec* or sea-wrack, *fuci*, &c. The ashes of these plants contain abundance of fixed alkali, which may be extracted and purified by lixiviating them, and then evaporating the ley. This is what is known in commerce under the name of *soda*.

Fixed vegetable alkali is commonly obtained by the combustion of the greater part of other plants, and of wood, such as common fire wood. A great deal is made, in this manner, in different forests, where immense quantities of wood are burnt for that purpose in pits; the ashes which remain contain abundance of this fixed alkali, known in the shops under the name of *potashes*. By lixiviating

m, and then evaporating the ley, an alkali much more ive may be obtained.

Another method of obtaining fixed vegetable alkali, ch purer, is to employ wine lees, and the tartar which ieres to the sides of wine casks. These substances are med into packets or masses of the size of the fist, and n burnt until they have assumed a white colour. By se means very pure fixed alkali may be produced. It nown in the shops under the name of *salt of tartar*, or *ıli of tartar*. It is absolutely the same as common pot-. In this state however they are not entirely free from ɔmbination of carbonic acid.

The two fixed alkalies, the vegetable and mineral, differ n each other principally by one peculiar property. The d vegetable alkali attracts the moisture of the air so ngly, that to preserve it in a solid state it must be put well closed vessels. If left exposed to the air, it deli-sces of itself, and in this state is called *oil of tartar per ɿuium;* an appellation very improper, for it is not an

In the other hand, fixed mineral alkali, instead of at-ting moisture, loses its own, and effloresces; that is, into dust; and for this reason it can be preserved with h more convenience than the other.

Volatile Alkali.

'his alkali, or ammonia, is produced by the combustion ıost animal matters, or by the putrefaction of animal egetable substances. The smell of putrified bodies is ıg to the alkali disengaged from them during that ation, by which nature reduces them in some mea- to their first principles, in order that they may serve ıew compositions. The strong odour which proceeds ı privies is a highly volatile alkali. It is called *volatile* use a heat, inferior even to that of boiling water, is

sufficient to disperse it in vapours, which always discover themselves by their penetrating smell.

§ III. *Of Neutral Salts.*

When a salt is neither acid nor alkaline, if it neither turns syrop of violets or blue paper red or green *, it is called *neutral*. The reason of this appellation is evident. Of this kind are marine salt, nitre, the different species of vitriol found in a natural state, and various other salts, both natural and artificial.

A neutral salt consists of an acid combined with an alkali, an earth, or a metal. We shall here give a few examples, enumerating the most common combinations of the three principal mineral acids, with different substances.

Thus, vitriolic acid, combined with zinc, forms white vitriol (sulphate of zinc);

With copper, blue vitriol;

With iron, green vitriol;

With argillaceous earth, alum;

With calcareous earth, selenite;

With volatile alkali, ammoniacal vitriol;

With fixed mineral alkali, Glauber's, Epsom, or Seidlitz salt;

With fixed vegetable alkali, vitriolated tartar.

Salts so formed are called sulphates; as sulphate of iron, of copper, of zinc, of ammonia, &c, according as one or other of these substances is united with the acid.

The nitric acid, combined with fixed vegetable alkali, forms nitre;

With fixed mineral alkali, quadrangular or cubic nitre;

With volatile alkali, a nitrous ammoniacal salt;

* This rule is liable to some exceptions. It may however be followed without any danger of much mistake.

'ith silver, a peculiar salt fusible by a moderate heat, wn under the name of *lapis infernalis*, on account of its ticity.

hese combinations are called *nitrates* of the substances ed to the nitric acid.

he marine acid, combined with fixed mineral alkali, s common marine salt, or muriate of soda;

'ith fixed vegetable alkali, febrifuge salt of Sylvius, or ate of potash:

'ith volatile alkali, sal ammoniac;

'ith mercury, if digested on it long enough to oxidate netal completely, it forms corrosive sublimate.

'hen this muriate is not perfectly saturated with oxy- it forms a salt salled *mercurius dulcis.*

l neutral salts, composed of marine or muriatic acid, ined with alkalies, earths, or metals, are called muri-

ie vegetable acid, called the tartareous, combined fixed vegetable alkali, forms tartar:

ith fixed mineral alkali, the salt called *vegetable salt, ettes salt, or Sal polychrest:*

etic acid, when combined with vegetable alkali, forms called *foliated earth of tartar* (acetate of potash):

ith copper it forms verdigris (acetate of copper); a rell known in commerce, and a violent poison:

ith lead it forms a salt called *saccharum saturni* ate of lead), which is also a poison and employed in rts.

ith mercury, acetate of mercury, a salt of great use es of syphilis.

e shall confine ourselves to this brief account of the nown compositions of the different acids with differ- ubstances. The number however might have been lerably increased; for every acid may be combined almost all the alkalies, earths, and metals.

ARTICLE II.

Of Oxygen.

We have already had occasion to mention this substance, for a knowledge of which we are indebted to modern chemistry. It has never been obtained alone; but its presence and effects are now so well known, that its existence may be considered as demonstrated. We shall here observe that almost all the phenomena explained formerly, by admitting the agency of an ideal principle, to which the old chemists gave the name of *phlogiston*, are now known to be produced by a play of chemical affinities, in which oxygen performs a conspicuous part. Thus, for example, in what used to be called the *calcination*, but now the *oxydation*, of metals, it was believed that the metals parted with phlogiston. It is however shown by experiment, that instead of parting with any thing, they receive an increase of weight; and it is known also, by taking proper care to perform the experiments in close vessels, that the air not only loses in its volume, but suffers also a diminution of its weight equal to what the metal has gained. But besides, the oxygen may be again separated from the metal, which yields a quantity of gas equal in weight and volume to what had been taken from the air by the metal.

The oxygen gas, thus separated from an oxide, is found to be that part of the atmosphere which serves for respiration; it is therefore called also *vital air*. When a metal, such as mercury for example, has been converted into an oxide, by exposure with heat, to atmospheric air, in a close vessel, the air which remains after all the oxygenous part has been taken up by the metal, is found to be a suffocating gas, distinguished by the name of *azotic gas*. It is not only unfit for respiration, but incapable of maintaining combustion; whereas oxygen gas, which may be separated

ı the oxide of mercury, or of manganese, &c, is better
›ted for promoting combustion than atmospheric air
f; so that many substances, which will not inflame in
mon air, burn with great violence in oxygen gas. We
mention one for the sake of illustration. If a piece
nall iron wire, with a bit of lighted tinder to begin the
bustion, be introduced into a vessel containing oxygen
it will burn with much greater intensity than flax or
›n, even though dipt in oil, will do in atmospheric

om this, and other considerations, which it would be
edious here to enumerate, it is inferred that the oxy-
in calces or oxides, in acids, and in all other combina-
, the gaseous ones excepted, is in a concrete state;
hat in the gaseous state it is united to something else,
ly the matter of heat, or of light, or of both; and
this theory the process of combustion is thus ex-
ed: during the process, the oxygen of the oxygenous
of the atmosphere unites itself to the burning body;
he heat and light which were united with the oxygen,
vhich held it in chemical solution, are liberated, pro-
ıg that phenomenon commonly called burning. The
and light therefore are not furnished by the burning
, but by the air.
hen carbonaceous matters, such as coals, wood, &c, are
oyed in the process, a portion of the liberated heat is
taken up by a new gas which has been formed, namely,
nic acid gas or fixed air, which we have already had
ion to mention *. It is the same, in every respect,
gas that may be separated from limestone or chalk,
posing it to heat. The matter of heat or *caloric* gives
gaseous form; and oxygen communicates to it its

ıere are a variety of gases which all differ in many of their proper-
›m common air; but to enter upon them would extend the present
beyond the limits which must be allotted to it.

acid properties. All acids indeed, as already mentioned, are indebted for their acidity to oxygen. Acidifiable bases, fully saturated with oxygen, produce acids; others, such as the metals, become oxides; but if means could be devised to saturate them completely, it is probable they would all produce acids. Some of them indeed have been brought to this state.

Having had occasion, in speaking of the vitriolic acid, to mention the part which oxygen has in the formation of acids, it is needless to say any thing farther on that subject.

ARTICLE III.

Of Affinities.

It is also necessary that we should here say a few words respecting affinities; as they are a key which serves to explain a great number of chemical compositions and decompositions.

Affinity is the force with which two substances tend to combine and maintain themselves in a state of union. Thus, for example, if vitriolic acid be poured over chalk, it drives out the carbonic acid, or fixed air, before united to it; lays hold of the calcareous earth; combines with it, and forms a mixture which is neither earth nor acid; but if fixed alkali, whether vegetable or mineral, be added to the solution, the calcareous earth will be expelled from its place; the vitriolic acid will seize on the fixed alkali, abandoning the former, and will thus form a new salt—an alkaline sulphate.

The moleculæ of the calcareous earth, and those of the vitriolic acid, have therefore a stronger tendency to unite, than those of the same earth and carbonic acid. The union is so perfect, that the fluid, though one of the ingredients in the compound be an earth, passes through a filtre. And hence it appears, that this result is not a mere

sion and interposition of the particles of the stone, be-
en those of the solvent, as was supposed, and is still
eved by some, who are not acquainted with the princi-
of chemistry. But, we might ask such persons, why
the particles of iron, dissolved in an acid, maintain
nselves in the liquor, notwithstanding their excess of
ific gravity? for, according to their philosophy, this
explicable. But if each particle of the iron be united
ach particle of the solvent, the difficulty will vanish;
if we admit this principle, and also an inequality of
e in the above tendency, all the phenomena of chemistry
be so easily explained, that the existence of such a
e in the particles of bodies cannot be denied.

esides, we have positive proofs of the force with which
shed surfaces adhere, independently of any surround-
fluid. Nothing then is more natural, than to conceive
nilar force between the minute particles of bodies: it
be sufficient to suppose them to have small facets of
rent forms and sizes, by which they adhere with a
e that may be subject to very complex laws; since it
depend on the extent of the facet, the density and
n of the particle; for these may produce a great many
ations.

hese affinities or tendencies are indeed very unequal,
by way of example we shall observe, that the force
which calcareous earth combines with vitriolic acid,
ss than that with which it combines with any alkali.
this account an alkali may be substituted instead of
areous earth. All acids, in general, have more affinity
alkalies than for calcareous earths; for the latter than
metals; and for some metals, than for others; which
ishes an easy method of decomposing certain mixtures.
he course of this part we shall give a few curious and
ructive examples.

ARTICLE IV.

Solution and Precipitation.

Solution is an operation, by which a fluid combines with the moleculæ of a solid, or of another fluid; so that each particle of the one contracts an adhesion with each particle of the other. This union or adhesion is produced by the affinity of these particles for each other; because, if a greater or less affinity does not exist, there can be no solution.

Solution does not consist in a mere attenuation of the body dissolved, and an interposition of its moleculæ between that of the fluid. When there is only an interposition of this kind, a separation soon takes place.

Precipitation is effected when the moleculæ of the dissolved body, being abandoned by the solvent, fall to the bottom of the liquor. This happens sometimes in consequence of a mere diminution in the force of the solvent, produced by diluting it with a great deal of water; but it is produced, for the most part, by presenting to the solvent some body for which it has a greater affinity than for the body already dissolved. For example, if a fixed alkali be poured into nitrous acid, holding in solution calcareous earth, the acid will seize on the alkali, on account of its greater affinity, and will abandon the earth, which will fall to the bottom of the vessel.

At other times, precipitation takes place, in consequence of presenting to the solution a body which, by combining with the dissolved body, forms a new mixture, insoluble in the solvent. Of this we have an example in the following operation: If calcareous earth be dissolved in nitrous or marine acid, on pouring into the solution vitriolic acid, the latter will seize on the earth, and form with it sulphate of lime, well known under the name of selenite. But as selenite is not soluble in these acids, nor even in water,

less it be in very large quantity, it falls to the bottom. ie same thing takes place when vitriolic acid is poured o a solution of mercury in nitrous acid: the particles ecipitated form what is called *white precipitate*.

ARTICLE V.

Effervescence and Fermentation. Difference between them.

Nothing is more common than for those who have but le knowledge of chemistry to confound these two phe- nena; which however are essentially different: and it st be allowed that, till within a few years, the French mists confounded these terms, though they did not found the operations which they denote.

Effervescence is the motion, accompanied with heat, ich often takes place during a solution. Thus, for ex- ple, when a little nitrous acid is poured over copper- ıgs; or when vitriolic acid is poured over those of iron; when a small quantity of the same acid is poured over :areous earth, a violent ebullition is excited, till the ıbination is formed, when the commotion subsides, and liquor becomes transparent. Such, in a few words, is rvescence*. Hence it is said that acids, in general, rvesce with alkalies, with metals, and with calcareous :hs.

But fermentation is entirely different: it is the intestine spontaneous motion, produced in certain liquors, ex- ted from vegetable matters; and which, from being et and insipid, renders them spiritous and vinous. st, for example, or the expressed juice of grapes, is

* In this case, one of the gasses, alluded to in a former note, is produced, ly, *hydrogen gas* or inflammable air. It has the property of burning once inflamed: if mixed with atmospheric air, and then set fire to, it des like gunpowder.

not wine; there is not a single drop of spirit in it; but when exposed to a moderate heat, a play of affinities takes place, by which the liquor becomes turbid of itself, is internally agitated, throws up bubbles, which are found to be fixed air; and when the disengagement of these bubbles ceases, it is entirely a new liquor, spiritous, intoxicating, &c. The case is the same with beer, produced by the fermentation of malt, or the strong decoction of barley, prepared in a certain manner. This, as may be seen, is an operation very different from effervescence, as above described. When a person therefore, speaking on chemical subjects, confounds these two words, the ears of the enlightened chemist are as much shocked, as those of a philosopher would be, were he to hear abhorrence of a vacuum employed to explain any of the phenomena of nature.

ARTICLE VI.

Of Crystallisation.

This appellation is given to that peculiar arrangement, which the greater part of salts, and even other bodies, affect to assume, after their solution in a liquid, when their parts, brought sufficiently near to each other by evaporation, dispose themselves in groupes. As rock crystal was the first body in which this regular arrangement was observed, its name has been given to that discovered in many other bodies, and particularly salts, by the subsequent researches of chemists and naturalists.

Dissolve common salt in water, and evaporate the solution to a certain degree; if it be then left at rest in a cool place, the saline particles, brought near to each other, and falling together to the bottom of the vessel, or attaching themselves to the sides of the vessel, will form masses, in which the cubic figure will be easily distinguished; as prisms of six sides terminating in pyramids, implanted in

h other, are distinguished in rock crystal. If crystaltion be promoted at the surface, by evaporating the nid, it takes place in the form of truncated square amids, composed of small cubes, heaped together in a tain order, one upon the other; as has been shown by Rouelle, who has explained the phenomenon with great enuity.

f the salt held in solution be saltpetre, the crystals ned will be hexagonal prisms, terminated by hexagonal amids.

n short, each salt affects a peculiar form.

lum crystalises in exact octaedra, that is, figures ned of two quadrangular pyramids, having a common are base.

'itriol of iron forms crystals which are oblique-angled es, or cubes the six faces of which are rhombuses with qual sides.

'he crystals of blue vitriol are compressed dodecaedra, form of which cannot be described in a few words.

'erdigrise, or the salt produced by a combination of gar and copper, forms crystals which are obliqueled parallelopipedons.

Crystallised or candied sugar forms quadrangular ms, cut obliquely by an inclined plane.

ut, as before observed, there are a multitude of other ies, besides salts, which possess the same property, of ing themselves into masses, and affecting the same llar figures. Most ores and pyrites are distinguished heir particular form: mineralised lead, for example, a great tendency to the right-angled or oblique-angled ical form. Even stones, in such cases, observe a cerregularity. The crystals of gypsum, or plaster of is, are shaped like the point of a lance; and gypsum efore is properly a salt. Calcareous spar, known under name of *Icelandic crystal*, is always an oblique-angled

parallelopipedon, inclined in the direction of its diagonal, and at determinate angles. In short, when metals cool slowly, their particles are at liberty to arrange themselves in a regular form; and it was long ago remarked that this was the case with antimony, and has since been observed in regard to iron, copper, zinc, &c.

As this phenomenon is one of the most curious in chemistry, it would afford matter for a very long article; but as we have given a short view of the subject, we must refer the reader for further information to the *Essai de Cristallographie* of Romé Delisle, which appeared in 1772, 8vo, and to the *Abbé Haüy's* late work on the same subject.

We shall now give a series of chemical experiments, which will be partly an application of the before-mentioned principles, or which will exhibit curious phenomena.

ARTICLE VII.

Various Chemical Experiments.

EXPERIMENT I.

How a body of a combustible nature may be continually penetrated by fire without being consumed.

Put into an iron box a piece of charcoal, sufficient to fill it entirely, and solder on the lid. If the box be then thrown into the fire, it will become red, and it may even be left in it for several hours, or days. When opened after it has cooled, the charcoal will be found entire, though there can be no doubt of its having been penetrated by the matter of the fire, as well as the whole metal of the box which contains it.

The cause of this effect is as follows. Before charcoal, or any other combustible body, can be consumed, oxygen must have access to it; but the contact of the atmosphere is prevented by the iron case being made quite close.

Hence too it happens, that coals covered with ashes juire much longer time to be consumed, than if they re exposed to the open air. This phenomenon, though ll known, could not be explained by any philosopher acquainted with the nature and properties of oxygen.

EXPERIMENT II.

Apparent Transmutation of iron into copper or silver.

Dissolve blue vitriol in water, till the latter is nearly urated; and immerse into the solution small plates of n, or coarse filings of that metal. These small plates iron, or filings, will be attacked and dissolved by the d of the vitriol; while its copper will be precipitated, l deposited in th^ place of the iron dissolved.

f the bit of iron be too large to be entirely dissolved, it l be so completely covered with the cupreous particles, t it will seem to be converted into copper. This is an eriment commonly exhibited to those who visit copper ies. At least, we have seen it performed at Saint-Bel, he Lyonnese. A key immersed some minutes in water, ected at the bottom of a copper-mine, was entirely of opper colour when drawn out.

f you dissolve mercury in marine acid, and immerse in bit of iron; or if this solution be rubbed over iron, it assume a silver colour. Jugglers sometimes exhibit chemical deception, at the expence of the credulous ignorant.

REMARK.—In this case, there is no real transmutation, merely the appearance of one. The iron is not coned into copper; the latter, held in solution by the or impregnated with the vitriolic acid, is only deposited he place of the iron, with which the acid becomes rged. Every time indeed that a menstruum, holding substance in solution, is presented to another sub-

stance, which it can dissolve with more facility, it abandons the former, and becomes charged with the latter. This is so certain, that when the liquor which has deposited the copper is evaporated, it produces crystals of green vitriol, which, as is well known, are formed by the combination of the vitriolic acid with iron. And this also is practised in the mine before mentioned. The liquor in question, which is nothing but a pretty strong solution of blue vitriol, is put into casks, or large square reservoirs, and pieces of old iron, being then immersed in it, are at the end of some time converted into a sort of sediment, from which copper is extracted. The liquor thus charged with iron is evaporated to a certain degree, and wooden rods are immersed in it, which become covered with crystals of green vitriol.

This experiment may be made also by dissolving copper in the vitriolic acid, and then diluting the solution with a little water. This is a new proof that the liquor only deposits the copper with which it is charged.

EXPERIMENT III.

Different substances successively precipitated, by adding another to the solution.

In the former experiment we have seen copper precipitated by iron: we shall now show iron itself precipitated. For this purpose, throw into a solution of iron a small bit of zinc; and in proportion as the latter dissolves, the iron will fall to the bottom of the vessel: it may easily be known to be iron, because it will be susceptible of being attracted by the magnet.

If you are desirous to precipitate the zinc, nothing will be necessary but to throw into the solution a bit of calcareous stone, such as white marble, or any other stone capable of making lime; the vitriolic acid will attack this

w substance, and suffer to be deposited at the bottom the vessel a white powder, which is zinc.

To precipitate the lime or calcareous earth, pour into e solution liquid volatile alkali (spirit of hartshorn); the rth, being abandoned by the acid, will deposit itself at e bottom of the vessel.

The calcareous earth may be precipitated also, and much tter, by pouring into the liquor a solution of fixed ali, such as fixed vegetable alkali; or by throwing into fixed mineral alkali.

REMARK.—It is by a similar effect that hard water decomposes soap, instead of dissolving it, and suffers to be posited a greater or less quantity of calcareous earth, e manner in which this takes place is as follows.

Water in general is hard only because it holds in solution enite or gypsum (a combination of vitriolic acid with careous earth), which it has dissolved in its passage ough the bowels of the earth, or which has been formed the water first becoming impregnated with vitriolic ts, and afterwards in its course meeting with and disving a portion of calcareous earth.

On the other hand, soap is an artificial combination of ed alkali with oil, or with some other greasy substance; l which have no great affinity.

When soap therefore is dissolved in water impregnated h selenite, the vitriolic acid of the latter, having a ater tendency to unite with the fixed alkali than with calcareous earth, which enters into the composition of selenite, abandons that earth, and combines with the ed alkali, in such a manner, that the soap is decomed; and as the oil is immiscible with water, it is diffused ough it in the form of white flakes, while the calcare- earth of the selenite falls to the bottom.

Here we have a new example of the use of chemistry,

to account for certain common effects which are inexplicable to the philosopher, unacquainted with that science.

EXPERIMENT IV.

By the mixture of two transparent liquors to produce a blackish liquor. Method of making good ink.

Provide a solution of green or ferruginous vitriol, and an infusion of gall-nuts, or of any other astringent vegetable substance, such as oak-leaves, well clarified and filtred; if you then pour the one liquor into the other, the compound will immediately become obscure, and at last black.

If the liquor be suffered to remain at rest, the black matter suspended in it will fall to the bottom, and leave it transparent.

Remark.—This experiment may serve to explain the formation of common ink: for the ink we use is nothing else than a solution of green vitriol mixed with an infusion of gall-nuts, and a little gum. The blackness arises from the property which the gall-nuts have of precipitating, of a black or blue colour, the iron held in solution by the water impregnated with vitriolic acid; but as the iron would soon fall to the bottom, it is retained by the addition of gum, which gives to the water sufficient viscidity to prevent the iron from being precipitated.

The reader perhaps will not be displeased to find here the following recipe for making good ink.

Take one pound of gall-nuts, six ounces of gum arabic, six ounces of green copperas, and one gallon of common water or beer; pound the gall-nuts, and infuse them in a gentle heat, for twenty-four hours, without bringing the mixture to ebullition; then add the gum in powder. When the gum is dissolved, put in the green vitriol; if you then strain the mixture, you will obtain very fine ink.

EXPERIMENT V.

To produce inflammable and fulminating vapours.

Put into a moderately sized bottle, with a short and ide neck, three ounces of oil or spirit of vitriol, and relve ounces of common water. If you then throw into is mixture at different times an ounce or two of iron ings, a violent effervescence will take place, and white ipours will arise from it. On a taper being presented to e mouth of the bottle, these vapours will inflame, and oduce a violent detonation, which may be repeated veral times, as long as the liquor continues to furnish nilar vapours.

EXPERIMENT VI.

The Philosophical Candle.

Provide a bladder, into the orifice of which is inserted netal tube, some inches in length, and so constructed, at it can be fitted into the neck of a bottle, containing e same mixture as that used in the preceding experi- ent.

Having then suffered the atmospheric air to be expelled m the bottle by the elastic vapour of the solution, apply the mouth of it the orifice of the bladder, after care- ly expressing from it the common air*. The bladder these means will become filled with inflammable air; ich if you force out against the flame of a taper, by ssing the sides of the bladder, will form a jet of a beauti- green flame. This is what chemists call *a philosophical ndle.*

* Great care must be taken not to omit this precaution; for a mixture nflammable and atmospheric air will explode with violence, instead of ning.

detonating quality; if it be then washed, it will be found in a powder, which may be reduced without any danger by the usual means.

EXPERIMENT IX.

To make Fulminating Powder.

Mix together three parts of nitre, two of well dried alkali, and one of sulphur; if a little of this mixture be put into an iron spoon over a gentle fire capable however of melting the sulphur, when it acquires a certain degree of heat, it will detonate with a loud noise, like the report of a small cannon.

This would not be the case if the mixture were exposed to a heat too violent; the parts only most exposed to the fire would detonate, and by these means the effect would be greatly lessened.

If thrown on the fire, it would not detonate, and would produce no other effect than pure nitre, which indeed detonates but without any explosion.

EXPERIMENT X.

A liquor which becomes coloured and transparent alternately, when exposed to or removed from the contact of the external air.

Digest copper, that is to say dissolve it slowly by means of a gentle heat, in a strong solution of volatile alkali. As the solvent attacks the copper, it will acquire a beautiful blue colour. If you pour some of this liquor into a small bottle, till it is nearly full, and then close it well with a stopper, the colour will gradually become fainter and at last disappear. On opening the bottle, the colour will return; and this alternation may be produced as often as you choose.

EXPERIMENT XI.

Pretended production of Iron.

Take clay or the ashes of burnt vegetables or animals, id draw over them an artificial magnet. By these means ›u will often attract some particles of iron, which will :here to the magnet. You may then rest assured that › iron, in a metallic state, remains in the earth or ashes. Then mix the remaining earth or ashes with pounded arcoal, and having formed the mixture into a paste with seed oil, put the whole into a crucible, and expose it to red heat for some time, but not intense enough to proce vitrification. When the mass is cold, and reduced to st, if the artificial magnet be again drawn over it, a eat many iron particles will be attracted by it, and will here to it.

Remark.—Some have pretended to give this experint as a proof that iron may be produced by clay and seed oil. A celebrated chemist, member of the Academy Sciences, even entertained this idea, notwithstanding : opposition he experienced from one of his brother mbers. But, in our opinion, no chemist at present will in it a production of iron.

t would indeed be wrong to suppose, after the iron nd at first by the magnet has been extracted, that no re remains in it. The magnet attracts iron only in its tallic state, or when it approaches near to it; but some l remains in the state of an oxide, and in this state it is susceptible of being attracted by the magnet, as may proved by an experiment made on oxide formed artiilly by the torrefaction of iron, or on the rust of that al.

Besides, it is well known that, of all the metals, iron is most universally diffused throughout the earth; it is

the colouring principle of common or red clay, and when clay is so coloured, it contains iron.

What then is the effect of the torrefaction of clay with charcoal dust and linseed oil, or any other fat oily body which has a strong affinity for oxygen? Such bodies having a greater affinity for that principle than iron has, by the aid of a proper temperature they decompose the oxide, and seizing on its oxygen, leave the iron in a metallic state, and consequently susceptible of being attracted by the magnet. This is the whole secret of the operation.

But it may be said, what reason is there to think that these wood-ashes contain iron? In answer to this question, we shall observe, that iron being diffused in great abundance throughout all nature, it is a constituent part in a great many vegetable productions: in some of them it is found in a metallic state; that it is susceptible of great attenuation; and that when dissolved in any liquid, it passes with it, through the filtre, at least in part. Hence it may easily ascend with the sap of plants; it circulates in the human body with the blood: in short, some even assert that plants are coloured by this metal with the concurrence of light; so that without iron and light all plants would be entirely white.

EXPERIMENT XII.

When two liquids are mixed together, to form a solid body, or at least a body which has consistence.

Make a highly concentrated solution of fixed alkali, and another of nitrate of lime: if the two solutions be mixed together, there will be an abundant precipitation of a matter which will assume a kind of solidity.

This phenomenon appeared so wonderful to the old chemists, that the operation by which it is produced was

alled the *chemical miracle*. There is however nothing onderful in it; for what takes place is as follows:

The two solutions being mixed, the nitrous acid abanons the earth, to seize on the fixed alkali, and with it reains in solution and transparent in the supernatant liquor. he earth is then precipitated, and forms the solid body hich results from the mixture.

We shall here give another operation, which might with ore justice be called a *chemical miracle*. We are inbted for it to a remark of M. de Lassonne, first phyian to the queen.

EXPERIMENT XIII.

form a combination, which when cold is liquid and transparent; but which when warm becomes thick and opake.

Put equal quantities of fixed alkali, either mineral or getable, and of well pulverised quick-lime, into a sufient quantity of water, and expose it to a strong and edy ebullition. Then filtre the product, which at first l pass through with difficulty, but afterwards with more e, and preserve it in a bottle well stopped. This liquor en made to boil, either in the bottle or in any other sel, will become turbid, and assume the consistence of y thick glue; but when cold it will recover its fluidity l transparency; and this alternation may be repeated as n as you choose.

I. de Lassonne made many experiments to discover the se of this singular phenomenon; and he assigns one ch may be seen in the *Mémoires de l'Academie des nces* for 1773.

EXPERIMENT XIV.

To make a flash, like that of lightening, appear in a room, when any one enters it with a lighted candle.

Dissolve camphor in spirit of wine, and deposit the vessel containing the solution in a very close room, where the spirit of wine must be made to evaporate by speedy and strong ebullition. If any one then enters the room with a lighted candle, the air will inflame; but the combustion will be so sudden, and of so short duration, as not to occasion any danger.

It is not improbable that the same effect might be produced, by filling the air of an apartment with the dust of the seed of a certain kind of lycoperdon, which is inflammable; for this seed, which is exceedingly minute, and like fine dust, inflames in the same manner as the pulverised resin used for the torches of the furies, and for representing lightening at the opera. And perhaps it would be better to substitute it for resin, as it does not produce that strong smell, which results from the latter, when burnt, and which is so disagreeable to the spectators.

EXPERIMENT XV.

Of Sympathetic Inks; and some tricks which may be performed by means of them.

Sympathetic inks are certain liquors which alone, and in their natural state, are colourless; but which by being mixed with each other, or by some particular circumstance, assume a certain colour.

Chemistry presents us with a great many liquors of this kind, the most curious of which we shall here describe.

1st. If you write with a solution of green vitriol, to which a little acid has been added, the writing will be perfectly colourless and invisible. To render it visible, nothing will be necessary but to immerse the paper in an

ıfusion of gall nuts in water, or to draw a sponge moisten-
d with the water over it. Those who have observed the
th experiment may readily see, that in this case the ink
is been formed on the paper. In the making of ink the
ro ingredients are combined before they are used for
riting; here they are not combined till the writing is
ıished: this is the whole difference.

2d. If you are desirous of having an ink that shall be-
me blue, you must write with a solution of green vitriol,
id moisten the writing with a liquor prepared in the fol-
wing manner:

Make four ounces of tartar, mixed with the same quan-
y of nitre, to detonate on charcoal; then put this alkali
:o a crucible with four ounces of dried ox blood, and
ver the crucible with a lid, having in it only one small
erture; calcine the mixture over a moderate fire, till no
ıre smoke issues from it; and then bring the whole to a
derate red heat. Take the matter from the crucible
l immerse it, while still red, in two quarts of water,
ere it will dissolve by ebullition; and when the liquor
been reduced to one half, it will be ready for use. If
u then moisten with it the writing above mentioned, it
l immediately assume a beautiful blue colour. In this
ration, instead of black ink, there is formed Prussian
e.

d. If you dissolve bismuth in nitrous acid, and write
h the solution, the letters will be invisible. To make
m appear, you must employ the following liquor:

Boil a strong solution of fixed alkali with sulphur, re-
ed to a very fine powder, until it dissolves as much of
s it can: the result will be a liquor which exhales va-
ırs of a very disagreeable odour, and to which if the
ve writing be exposed it will become black.

th. But of all the kinds of sympathetic ink, the most
ous is that made with cobalt. It is a very singular

phenomenon, that the characters or figures traced out with this ink may be made to disappear and to re-appear at pleasure: this property is peculiar to ink obtained from cobalt; for all the other kinds are at first invisible, until some substance has been applied to make them appear; but when once they have appeared they remain. That made with cobalt may be made to appear and to disappear any number of times at pleasure.

To prepare this ink, take zaffre, and dissolve it in aqua-regia (nitro-muriatic acid) till the acid extracts from it every thing it can; that is the metallic part of the cobalt, which communicates to the zaffre its blue colour; then dilute the solution, which is very acrid, with common water. If you write with this liquor on paper, the characters will be invisible; but when exposed to a sufficient degree of heat, they will become green. When the paper has cooled they will disappear.

It must however be observed, that if the paper be heated too much, they will not disappear at all.

Remark.—With this kind of ink some very ingenious and amusing tricks, such as the following, may be performed.

1st. *To make a drawing which shall alternately represent summer and winter.*

Draw a landscape, and delineate the ground and the trunks of the trees with the usual colours employed for that purpose; but the grass and leaves of the trees with the liquor above-mentioned. By these means you will have a drawing, which at the common temperature of the atmosphere will represent a winter-piece; but if it be exposed to a proper degree of heat, not too strong, you will see the ground become covered with verdure and the trees with leaves, so as to represent a view in summer.

Screens painted in this manner were formerly made at

Paris. Those to whom they were presented, if unacquainted with the artifice, were astonished to find when they made use of them, that the views they exhibited were totally changed.

2d. *The Magic Oracle.*

Write on several leaves of paper, with common ink, a certain number of questions, and below each question write the answer with the above kind of sympathetic ink. The same question must be written on several pieces of paper, but with different answers, that the artifice may be better concealed.

Then provide a box, to which you may give the name of the Sybil's cave, or any other at pleasure, and containing in the lid a plate of iron made very hot, in order that the inside of it may be heated to a certain degree.

Having selected some of the questions, take the bits of paper containing them, and tell the company that you are going to send them to the Sybil or Oracle, to obtain an answer; introduce them into the heated box, and when they have remained in it some minutes take them out, and show the answers which have been written.

You must however soon lay aside the bits of paper; for if they remain long in the hands of those to whom the trick is exhibited, they would see the answers gradually disappear, as the paper becomes cold.

EXPERIMENT XVI.

Of Metallic Vegetations.

To see a shrub rise up in a bottle, and even throw out branches, and sometimes a kind of fruit, is one of the most curious spectacles exhibited by chemistry. The operation by which this delusive image is produced has been called chemical or metallic vegetation, because performed by means of metallic substances; and it is not im-

probable that some respectable persons, who thought they saw a real palingenesy, have been deceived by a similar artifice. However this may be, the following are the most curious of these vegetations, which in fact are only a kind of crystallizations.

Arbor Martis, Tree of Mars.

Dissolve iron filings in spirit of nitre (aquafortis) moderately concentrated, till the acid is saturated; then pour gradually into the solution a solution of fixed alkali, commonly called oil of tartar per deliquium. A strong effervescence will take place; and the iron, instead of falling to the bottom of the vessel, will afterwards rise, so as to cover its sides, forming a multitude of ramifications heaped one upon the other, which will sometimes pass over the edge of the vessel, and extend themselves on the outside, with all the appearance of a plant. If any of the liquor be spilt, it must be carefully collected, and be again put into the vessel, where it will form new ramifications, which will contribute to increase the mass of the vegetation.

Two of these vegetations, copied from a memoir of M. Lemery junior, and inserted among those of the Academy of Sciences for 1706, are represented pl. 8, fig. 46. A very probable explanation of the phenomenon may be found among those of 1707.

Arbor Dianæ, Tree of Diana.

This kind of vegetation is called the Tree of Diana, because it is formed by means of silver; as the former is called the Tree of Mars, because produced by iron. We shall here give two processes for this purpose, one of them by Lemery, and the other by Homberg.

Dissolve an ounce of pure silver in a sufficient quantity of aquafortis, exceedingly pure, and of a moderate strength, and having put the solution into a jar, dilute it

ith about twenty ounces of distilled water. Then add ro ounces of mercury, and leave the whole at rest. In e course of forty days, there will rise from the mercury kind of tree, which throwing out branches will represent natural vegetation.

Should this process, which is in other respects very simle, be thought too tedious as to time, the following one ' Homberg may be employed.

Form an amalgam of a quarter of an ounce of very pure ercury, and half an ounce of fine silver reduced into ings or leaves, that is to say, mix them together by triration in a porphyry mortar, by means of an iron pestle. issolve this amalgam in four ounces of very pure nitric id, moderately strong, and dilute the solution in about pound and a half of distilled water, which must be stird, and then preserved in a bottle well stopped. Pour an ince of this liquor into a glass, and throw into it a small t of an amalgam of mercury and silver, similar to the rmer, and of the consistence of butter. Soon after you ll see rising from the ball of amalgam a multitude of small aments, which will visibly increase in size, and throwing it branches will form a kind of shrubs.

Homberg, in the Memoirs of the Academy for 1710, ves a method of making a similar vegetation, either with ld or silver, in the dry way; that is to say by distillan without any solution.

There is still another kind of vegetation, mentioned by de Morveau, which he calls *Jupiter's beard*, because tin ms a part of its composition: the process for making may be seen in his *Essais Chimiques*.

Non-metallic Vegetation.

Cause to decrepitate, on burning charcoal, eight ounces saltpetre, and place it in a cellar, in order that it may oduce oil of tartar per deliquium; then gradually pou

over it, to complete saturation, good spirit of vitriol, and evaporate all the moisture. The result will be a white, compact, and very acrid saline matter. Put this matter into an earthen dish, and having poured over it a gallon of cold water, leave it exposed to the open air. At the end of some days the water will evaporate, and there will be found all around the vessel ramifications in the form of needles, variously interwoven with each other, and about 15 lines in length. When the water is entirely evaporated, if more be added the vegetation will continue.

It may be readily seen that this is nothing but the mere crystallization of a neutral salt, formed by the vitriolic acid and the alkali of the nitre employed, that is to say, vitriolated tartar.

EXPERIMENT XVII.

To produce Heat, and even Flame, by means of two Cold Liquors.

Put oil of guiacum into a bason, and provide some spirit of nitre, so much concentrated, that a small bottle, capable of holding an ounce of water, may contain nearly an ounce and a half of this acid. Make fast the bottle containing the acid, to the end of a long stick, and after taking this precaution pour about two thirds of the acid into the oil in the bason; the result will be a strong effervescence, followed by a very large flame. If an inflammation does not take place in the course of a few seconds, you have nothing to do but to pour the remainder of the nitrous acid over the blackest part of the oil: a flame will then certainly be produced, and there will remain, after the combustion, a very large spongy kind of charcoal.

Oil of turpentine, oil of sassafras, and every other kind of essential oil, may be made to inflame in the like manner. The same phenomenon may be produced with fat oils, such as olive oil, nut oil, and others extracted by ex-

ression, if an acid, formed by equal parts of the vitriolic nd nitrous acids well concentrated, be poured into them.

EXPERIMENT XVIII.

To fuse iron in a moment, and make it run into drops.

Bring a rod of iron to a white heat, and then apply to a roll of sulphur; the iron will be immediately fused, ıd will run down in drops. It will be most convenient perform this experiment over a bason of water, in hich the drops that fall down will be quenched. On exnination, they will be found reduced into a kind of cast on.

This process is employed for making shot used in huntg, as the drops, by falling into the water, naturally asıme a round form.

We shall here add two little experiments, merely beuse they are usually given in books of Philosophical ecreations.

EXPERIMENT XIX.

o fuse a piece of money in a walnut-shell, without injuring the shell.

Bend any very thin coin, and having put it into the half a walnut-shell, place the shell on a little sand, in order at it may remain steady. Then fill the shell with a mixre made with three parts of very dry pounded nitre, one rt of the flowers of sulphur, and a little saw-dust well ted.

If you then inflame the mixture, as soon as it has melted, u will see the metal completely fused in the bottom of e shell in the form of a button, which will become hard ıen the burning matter around it is consumed. The shell ıployed for the operation will have sustained very little jury. The cause of this, no doubt, is that the activity

of the fire, assisted by the vitriolic acid contained in the sulphur, acts with such rapidity, that it has not time to burn the shell.

A small ball of lead, closely wrapped up, in a bit of paper *, may be fused in the same manner, by exposing it to the flame of a candle. The paper will not be hurt, except in the bottom, where it will have a small hole through which the metal has run.

EXPERIMENT XX.

To split a piece of money into two parts.

Fix three pins in the table, and lay the piece of money upon them; then place a heap of the flowers of sulphur below the piece of money, and another above it, and set fire to them. When the flame is extinct, you will find on the upper part of the piece a thin plate of metal, which has been detached from it.

It is to be observed that the value of about three-pence might be detached in this manner from a piece of gold such as a guinea, by employing sulphur to the value of fifteen or twenty-pence; so that this experiment can never become dangerous to the public. Besides the piece of money loses, in a great measure, the boldness of its impression: those therefore who might attempt to debase the current coin in this manner would become victims to their dishonesty.

What we have said is sufficient to inspire our readers with a desire to become better acquainted with this useful Science. We shall therefore point out to them a few works which will assist them in prosecuting that design. Though chemistry has experienced a complete revolution since the discoveries of Lavoisier, Priestley, Black, Hig-

* If the paper be not in perfect contact with the lead, the experiment will not succeed.

'ish, and others, some useful information may
' from the works of the old chemists: we
` may be allowed to introduce here *Les*
Theoretique et Practique of Macquer,
of which contains the theoretical,
·actical part. To this work we
Chimie of Baumé, which contains
.s processes useful in the arts. Boer-
of Chemistry were formerly held in great
out at present this work is of less value: it
ever serve as a good introduction to the modern
.stry. *Wiegleb's Chemistry*, translated by Hopson,
ough founded on the old theory, may also be perused
th advantage, by those who are desirous of acquiring a
orough knowledge of this Science. Also the chemical
orks of Bishop Watson. The best systems of chemistry,
d elementary works according to the new theory, are
ose of *Lavoisier*, *Fourcroy*, *Chaptal*, *Gren*, *Jacquin*,
illon-Lagrange, *Brisson*, *Thomson*, and *Davy*. As
oks of reference we can recommend *Henry's Manual*
d *Parkinson's Chemical Pocket Book*. A great many
rious and interesting papers on chemistry in general,
d its application to the arts, may be found also in the
ilosophical Magazine.

most difficult, method requires that you should execute the easiest. But we are acquainted with no chemical operation, which resolves either of these problems. Gold, as stubborn in regard to decomposition as to composition, always remains the same, in whatever manner it be treated: it is only more or less attenuated, but is never in the state of calx. It has been kept for several years in fusion, without losing the least part of its weight.

But let us hear the alchemists, and learn what are their pretensions in regard to the formation of metals.

According to them, metals are formed of an earth, which they call *mercurial*, but more or less mature, more or less mixed with heterogeneous matters; so that, to convert the imperfect into perfect metals, nothing is necessary but to free them from these heterogeneous matters, and to mature them.

All this is very fine: but who has proved the existence of this mercurial earth? who has proved that the difference among metals consists in this greater or less maturity? by what means is it to be produced? to these questions no solid answer can be given. The partisans of this idea seduced by words, have no just and precise conception of what they say.

According to other alchemists, mercury contains in principle all the perfect metals; it has the splendour of them, and nearly the weight; it is even heavier than silver. If it is fluid and exceedingly volatile, it is because it is alloyed with impurities which degrade it. The question then is to fix the mercury, by freeing it from these impurities. We should then have the mercury of the philosophers, which would require only a certain degree of baking to be brought to a red heat, and the result would be gold; brought to a white heat, it would furnish silver; nay this matter would have such an activity on the impure parts of other metals, that by throwing a pinch of it into

crucible filled with melted lead, it would transmute it ıto silver or gold, according as it had been carried to a hite or a red heat. But the great matter is, how to estroy the impurities by which quicksilver is debased. ristєus, a celebrated adept, teaches us the process in the learest manner, in his *Code de Verité*. "Take," says he, king Gabertin, and the princess Beya his sister, a young dy, beautiful, fair, and exceedingly delicate: marry them gether, and Gabertin will die almost immediately. Be ot however alarmed; after eighty days, Gabertin will reive from his ashes, and become more beautiful and more erfect than he was before his death; will beget with Beya red child more beautiful and perfect than themselves." fter this, will any one pretend to say that the alchemists cplain themselves obscurely? what true adept, for there re true and false, and every one thinks himself among the rmer, will not evidently see in this allegory the whole rocess of the fixation of mercury and of the powder of rojection?

This language, and this affectation of obscure allegories, e no doubt very proper for making these pretended lepts be considered as finished and contemptible quacks, perhaps as people whose brains have been deranged by e heat of their furnaces. But the partizans of their researches and follies allege pretended facts; and it is our siness to make them known.

It is related that Helvetius, a physician and celebrated ofessor in Holland, having declaimed one day with great olence, in one of his lectures, against the vanity and abrdity of pretending to make gold, was visited by an ept, who gave him a certain powder, a pinch of which rown into a crucible filled with melted lead, would transrm it into gold: that the learned Dutchman did so, and tained from his lead a considerable quantity of that

metal. Helvetius then hastened to find the adept; but the latter had given him a false address, and was not to be found; for the chemists of this order never fail to disappear at the moment when they have given a proof of their profound knowledge.

The same thing occurred, it is said, to the emperor Ferdinand. An adept came to him, and offered to transform mercury into gold. Mercury was put into a crucible in the presence of the prince, and the adept having performed certain operations, a button of gold was found in the bottom of the vessel. But while those present were employed in examining and essaying the gold, the adept disappeared, to the great regret of the emperor, who already beheld in idea the immense treasures which he hoped to obtain by the acquisition of this grand secret.

At the sale of the effects left by M. Geoffroy, in 1777, there were three nails, which as it was said were a proof of the possibility of at least transmuting silver into a common metal, such as iron. They were the work, he asserted, of a celebrated adept, who wished to prove to Geoffroy the possibility of the transmutation of metals. One of these nails was converted into silver, by being dipped in an appropriate liquor; the head of the other only having been dipped, the remainder of it was iron; and the point of the third, having been dipped, that part was silver and the head iron.

Notwithstanding these authorities, we have no belief in the philosopher's stone. It is very probable that in all these pretended transmutations there was some deception, even if the above accounts were true. In short, we shall believe in the philosopher's stone when we have seen any adept perform before us the same operations; but he must permit us to furnish him with the crucibles, rods, and ingredients; for it is more than probable, that if gold has

een made in this manner, it either existed in the matters mployed, or some of it was introduced into them by slight f hand.

However, the alchemists pretend that all the fables of ntiquity are nothing else than the process of the grand ork explained symbolically. The conquest of the golden eece, the Trojan war, the events which followed it, and e whole mythology, are only emblems of the chrysopea, rudently veiled by the ancient philosophers, who did not ish that their secret, become common, should be emloyed to produce an immense increase of the precious etals, which must then have lost their value, and have eased to be the medium of commerce among mankind. he reader may see in a curious work by Dom Pernetty, ntitled *Les Fables Egyptiennes et Grecques*, 3 vols. 8vo, cluding the *Dictionnaire Mytho-hermetique*, how far uman sagacity may be extended, to find an explanation such fables. But every thing may be explained in the me manner. We have heard of an adept, in the *Faurg Saint Marceau*, who, being persuaded that the hole Roman history was a fiction, intended to give a emical explanation of it, which would serve as a supplent to the *Fables Egyptiennes et Grecques*. We have en heard that the history of the combat of the Horatii d the Curiatii was explained in it, with an appearance truth, capable of making us doubt whether that famous cumstance in the Roman history ever really took place.

§ II. *Of Potable Gold.*

If there be no reason to think that gold will ever be de, is it not possible to employ this precious metal for olonging life? Gold is a metal unalterable, and as diffilt to be destroyed as to be made; it is the sovereign of metallic world, as the sun, to which it is assimilated, is he system of the universe. Nature therefore must have

concealed in this valuable body the most useful remedies; but to make it useful, in this respect, it is necessary that it should be introduced into the body in a liquid form; it must in short be rendered potable: let us endeavour then to make potable gold. A life indefinitely prolonged is certainly worth all the treasures in the world. Such is in substance the reasoning of the alchemists, and therefore they have subjected gold to a multitude of operations, by means of which they have pretended to render it soluble, like a salt in water. The substance they produce has indeed the appearance of it; but to speak the truth, it is only gold very much attenuated, and by these means suspended in the liquid: in short, it is in no manner combined with the fluid, and it even gradually deposits itself at the bottom in the metallic form.

However, the following is a process for making a kind of potable gold. We shall examine afterwards, supposing it to be a real solution of gold, whether it would possess properties so marvellous, and so salutary to the human body, as is pretended.

First dissolve gold in aquaregia: mix this solution with fifteen or sixteen times the quantity of any essential oil, such as that of rosemary, stirring it round, and separate the aquaregia, which occupies the bottom, from the essential oil. If you then dissolve this essential oil in four or five times its weight of well rectified spirit of wine, you will have a yellowish liquor known under the name of the *potable gold of Mademoiselle Grimaldi.*

Vitriolic ether, and ethereal liquids of different kinds, possess the same property as essential oils; namely, that of seizing on the gold dissolved in the aquaregia. A kind of potable gold therefore may be made with ether. This gold may then be taken in drops on sugar, in the same manner as when ether is taken; for this liquor is not miscible with water.

The celebrated drops of general Lamotte are not different from the potable gold of mademoiselle Grimaldi. It has been remarked that one gros of gold was diluted in 216 gros of spirituous liquor, and as the bottles must have weighed two gros, and as general Lamotte sold his for 24 livres, it results that with one gros of gold he made at least 108 bottles, from the sale of which he received at least 2592 livres. In reality he made 136, which were worth to him 3264 livres.

It hence appears, that if general Lamotte's drops were not useful to the health, they were exceedingly useful to his purse. But what will not quackery effect among mankind, when supported by ignorance and the love of life?

But let us examine whether there be any foundation for the wonderful properties ascribed to potable gold. A very little reasoning will show that nothing can rest on a slighter foundation. What proofs indeed can the alchemists produce, that potable gold is salutary to the human body? Because gold is the most fixed of all metals, because it has the beautiful colour of the sun's rays, because it is represented in chemical characters by the characteristic sign of that luminary, are we thence to conclude that, when reduced to a liquid form, and conveyed into the blood, it regenerates that fluid, renovates youth, and restores health? What person, accustomed to deduce just consequences from any principle, will ever form such a conclusion? All the virtues of potable gold are founded merely on analogies, invented without any physical foundation, by fervid imaginations, and by heads deranged by the heat of their furnaces. This is the most favourable opinion that can be entertained; for it is probable that such ideas are as much connected with imposture, as with credulity and want of reasoning.

§ III. *Of Palingenesy.*

Palingenesy is a chemical operation, by means of which, a plant, or an animal, as some pretend, can be revived from its ashes. This, if true, would no doubt be one of the noblest secrets of chemistry and philosophy. If some authors are to be credited, several learned men of the 17th century were in possession of it; but at present, as this pretended secret, in consequence of the great progress made in chemistry, is considered as a mere chimera, we shall here confine ourselves to examining the foundation of those principles which have induced some respectable authors, such as the Abbé Vallemont* and others, to believe in the possibility of this process.

According to the honest Abbé, nothing is simpler and easier to be explained. We are indeed told, says he, by Father Kircher, that the seminal virtue of each mixture is contained in its salts; and these salts, unalterable by their nature, when put in motion by heat, rise in the vessel through the liquor in which they are diffused. Being then at liberty to arrange themselves at pleasure, they place themselves in that order in which they would be placed by the effect of vegetation, or the same as they occupied before the body, to which they belonged, had been decomposed by the fire: in short, they form a plant, or the phantom of a plant, which has a perfect resemblance to the one destroyed.

This reasoning is worthy of an author who could believe, that he who robs another of his money, can exhale corpuscles different from those exhaled by a man who carries his own, and thereby make the divining rod turn towards the places where he has passed, or remained for some time. Does it not show great weakness to believe,

* See *Les Curiosités de la Vegetation, &c.*

that the mere immorality of an action can produce physical effects? It would indeed be offering an insult to our readers, to attempt to show the folly and absurdity of the above reasoning of the good Abbé, and of Father Kircher. Let us therefore only examine the facts which he relates.

An English chemist, named Coxe, asserts that having extracted and dissolved the essential salts of fern, and then filtered the liquor, he observed, after leaving it at rest for five or six weeks, a vegetation of small ferns adhering to the bottom of the vessel. The same chemist, having mixed northern potash with an equal quantity of sal ammoniac, saw some time after a small forest of pines, and other trees, with which he was not acquainted, rising from the bottom of the vessel.

The following fact is considered by the author as more conclusive. The celebrated Boyle, though not very favourable to palingenesy, relates, that having dissolved in water some verdigris, which, as is well known, is produced by combining copper with the acid of vinegar, and having caused this water to congeal by means of artificial cold, he observed at the surface of the ice small figures, which had an exact resemblance to vines.

Notwithstanding these facts, and others quoted by the Abbé from Daniel Major, Hanneman, and various authors, if the partisans of palingenesy can produce none more conclusive, it must be confessed that they support their assertions by very weak proofs. Every true chemist sees in these phenomena nothing but a simple ramified crystallization, which may be produced by different well known compositions: the most beautiful of these crystallizations, called improperly *vegetations*, are produced by the combination of bodies from the animal kingdom.

The last experiment, related by Boyle, might occasion more embarrassment; but as it is the only one, of a great

many, made with the essential salts of a variety of plants, that succeeded, there can be no doubt that the figures he saw were the mere effect of chance; for how many other philosophers, who made the same attempt, saw nothing but what is exhibited, by the surface of frozen water, which sometimes forms ramifications exceedingly complex?

The partisans of palingenesy however quote other authorities, to which they attach great importance. We are told by Sir Kenelm Digby, on the authority of Quercetan, physician to Henry IV. of France, that a Pole showed twelve glass vessels hermetically sealed, each containing the salts of different plants: that at first these salts had the appearance of ashes, but that when exposed to a gentle and moderate heat, the figure of the plant, as a rose for example, if the vessel contained the ashes of a rose, was observed gradually to rise up, and that as the vessel cooled the whole disappeared. Sir Kenelm adds, that Father Kircher had assured him, that he performed the same experiment, and that he communicated to him the secret, but it never had succeeded. The story of this Pole is related by various other authors, such as Bary, in his *Physique*, and Guy de la Brosse, in his book on the Nature of Plants.

Lastly, we are told by Kircher himself, in his *Ars Magnetica*, that he had a long necked phial, hermetically sealed, containing the ashes of a plant which he could revive at pleasure, by means of heat; and that he showed this wonderful phenomenon to Christina, queen of Sweden, who was highly delighted with it; but that having left this valuable curiosity one cold day in his window, it was entirely destryed by the frost. Father Schott also asserts, that he saw this chemical wonder, which, according to his account, was a rose revived from its ashes; and he

adds, that a certain prince having requested Kircher to make him one of the same kind, he chose rather to give up his own, than to repeat the operation.

The process indeed, as taught by Kircher, is so complex and tedious, that it would require no small patience to follow it. Father Schott relates it at full length, in his work entitled *Jocoseria Naturæ et Artis*, and he calls it the Imperial secret, because the emperor Ferdinand purchased it from a chemist, who gave it to Kircher. This emperor was exceedingly fortunate; for it was to him that the philosopher, who had the secret of the philosopher's stone, addressed himself, and gave a proof of his art by transmuting, as is said, in his presence, three pounds of mercury into two pounds and a half of gold.

We must however content ourselves with pointing out the places where the curious may find this singular process; for besides the length of the description, nothing seems less calculated to succeed. Digby, therefore, and many others who followed this method, did not obtain a favourable result; and there is reason to believe that their zeal for palingenesy would induce them to omit nothing that was likely to insure them success.

Dobrezensky, of Negropont, has also given a process for the resurrection of plants, which seems to have been attended with no better success. We are at least told by Father Schott, that the attempts of Father Conrad proved ineffectual, and he therefore supposes that Dobrezensky did not reveal all the circumstances of the process, but kept the most important to himself.

What then can be said in opposition to all these authorities? In our opinion, the Polish physician was a quack, and we shall describe hereafter a method of producing a false palingenesy, which, if performed with art, and in a proper place, may impose on credulous persons. To be convined that Dobrezensky of Negropont was a

mere impostor, we need only read the *Technica Curiosa*, or the *Jocoseria Naturæ et Artis* of Father Schott; for he had the impudence to pretend that he could pull out the eye of an animal, and in the course of a few hours restore it, by means of a liquor, which he no doubt sold as a remedy for sore eyes. He even tried it on a cock. A person who could assert such an impudent falsehood, in regard to one fact, would do the same in regard to another.

The authority of Father Schott will certainly be of little weight with those who have read his works.

In regard to the testimony of Kircher, we confess that we find some embarrassment: a Jesuit certainly would not wilfully have told a falsehood. But Kircher was a man of a warm imagination, passionately fond of every thing singular and extraordinary, and who had a strong propensity to believe in the marvellous. What can be expected from a man of that character? He often thinks he sees what he does not see, and he does not deceive others, because he is first deceived himself.

Some persons go still farther, and assert that an animal may be revived from its ashes. Father Schott, in his *Physica Curiosa*, even gives the figure of a sparrow thus revived in a bottle. Gaffarel, in his *Unheard of Curiosities*, believes in this fact, and considers it as a proof of the possibility of the general resurrection of bodies. This pretended revival, however, is a chimera, still more absurd than the former; and which, at present, it would be ridiculous to attempt seriously to refute.

In short, what reasonable man can with Kircher believe, that if the ashes of a plant be scattered on the ground, plants of the like kind will spring up from them, as he says he frequently experienced? Who can admit as a truth, that if crabs be burnt, and then distilled, according to a process given by Digby, there will be produced in the liquor small crabs of the size of a grain of millet,

which must be nourished with ox's blood, and then left to themselves in some stream? yet we are told by Sir Kenelm, that this he himself experienced. It is therefore impossible to clear him from the charge of imposture, unless we suppose that by some means or other he was led into error. However, it is certain that Digby, with great zeal and a considerable share of knowledge, had a strong propensity to all the visions of the occult and cabalistic sciences. In our opinion, he was one of those visionaries known under the name of *Rosicrusians*.

An illusory kind of Palingenesy.

We have already mentioned a kind of slight of hand, by means of which, credulous people might easily be imposed on, and induced to believe in the reality of palingenesy. We shall now discharge our promise by describing it.

Provide a double glass jar of a moderate size, that is, a vessel formed of two jars placed one within the other, in such a manner, that an interval of only a line in diameter may be left between them. The vessel may be covered by an opake top or lid, so disposed, that by turning it in different directions, the inner jar may be raised from, or brought nearer to the bottom of the exterior one. In the interior jar, on a base representing a heap of ashes, place the stem of an artificial rose. Into the lower part of the interval between the two jars introduce a certain quantity of ashes, or some solid substance of a similar appearance; and let the remainder be filled with a composition made of one part of white wax, twelve parts of hog's lard, and one or two of clarified linseed oil. This oily compound, when cold, will entirely conceal the inside of the jar, but when brought near the fire, if done with dexterity, it will dissolve, and by shaking the lid, under a pretence of hastening the operation, the compound may be made to

fall down into the bottom of the exterior jar. The rose in the interior one will then be seen, and the credulous spectators, who must not be suffered to approach too near, will be surprised and astonished. When you wish to make the rose disappear, remove the jar from the fire, and by a new slight of hand make the dissolved semi-transparent wax flow back into the interval between the jars. By accompanying this manœuvre with proper words, the gaping spectators will be more easily deceived, and will retire firmly persuaded, that they have seen one of the most curious phenomena, that can be exhibited by the united efforts of chemistry and philosophy.

SUPPLEMENT I.

Of the different kinds of Phosphorus, both natural and artificial.

ONE of the most interesting objects in chemistry is phosphorus; for it is a very singular and curious spectacle, to see a body, absolutely cold, emit a light of greater or less vivacity, and others kindle of themselves, without the application of fire. What person, who has any taste for the study of nature, will not be struck with astonishment, on viewing such phenomena?

These phenomena are the more remarkable, as most philosophers have hitherto failed in their attempts to explain them. We, however, except the artificial kinds of phosphorus, respecting which they have advanced things consistent with probability, and founded on chemical causes fully established. But, in regard to the natural kinds, nothing satisfactory has yet been offered. The explanation of them depends, no doubt, on a more profound knowledge of the nature of fire and light.

Some kinds of phosphorus are natural: others are the roduction of art, and particularly of chemistry. Hence e are furnished with a natural division of this supplement. Ve shall begin with the natural.

ARTICLE I.

Of the Natural Kinds of Phosphorus.

§. 1. *Of the Luminous appearance of the Sea.*

Though navigators must have observed this phenomenon r many centuries past, as it is common to every sea, and there is scarely any climate where it does not, under rtain circumstances, present itself, it appears that very tle attention has been paid to it till within a late period. ost sea-faring people believed, that this light was merely reflection of that of the stars, or of that of the vessel elf; others considering it as a real light, imputed it to collision of sulphur and salts; and, satisfied with this gue explanation, they scarcely condescended to pay ention to the phenomenon.

As it is highly worthy of profound research, and is atded with very remarkable circumstances, we shall here e a description of it, as it appeared to us on our passage m Europe to Guyana, in the year 1764.

do not recollect that we beheld the sea luminous till arrival between the tropics; but at that period, and e-weeks before we reached land, I almost constantly erved that the ship's wake was interspersed with a titude of luminous sparks, and so much the brighter as darkness was more perfect. The water around the der was, at length, entirely brilliant; and this light nded, gradually diminishing, along the whole wake. marked also, that if any of the ropes were immersed e water, they produced the same effect.

ut it was near land that this spectacle appeared in all

its beauty. It blew a fresh gale, and the whole sea was covered with small waves, which broke, after having rolled for some time. When a wave broke, a flash of light was produced; so that the whole sea, as far as the eye could reach, seemed to be covered with fire, alternately kindled and extinguished. This fire, in the open sea, that is at the distance of 50 or 60 leagues from the coasts of America, had a reddish cast. I have made this remark, because I do not know that any person ever examined the phenomenon which I am about to describe.

When we were in green water *, the spectacle changed. The same fresh gale continued; but in the night time, when steering an easy course, between the 3d and 4th degree of latitude, the fire above described assumed a tone entirely white, and similar to the light of the moon, which at that time was not above the horizon. The upper part of the small waves, with which the whole surface of the sea was curled, seemed like a sheet of silver; while on the preceding evening it had resembled a sheet of reddish gold. I cannot express how much I was amused and interested by this spectacle.

The following night it was still more beautiful; but at the same time more alarming in consequence of the circumstances under which I then found myself. The ship had cast anchor at a considerable distance from the land, waiting for the new moon, in order to enter the harbour of Cayenne. Being anxious to get on shore, I stepped into

* The water of the sea, at least of the Atlantic Ocean, at a distance from the coasts, is of a dark blue colour; but near land, that is to say, 20 or 25 leagues from the coast of Guyana, the water suddenly changes its colour, and becomes a beautiful green. This is a sign of being near land. This change, in all probability, is produced by the muddy, yellowish water of the river of the Amazons; for it is well known that blue and yellow form green. But a remarkable circumstance is, that this change is absolutely abrupt; it does not take place by degrees, but suddenly, and in an interval, which appeared to me, from the deck of the vessel, to be scarcely a foot in extent.

the boat with several other passengers; but scarcely had we got a league from the ship, when we entered a part of the sea where there was a prodigious swell, as a pretty smart gale then prevailed at south-east. We soon beheld tremendous waves, rolling in our wake, and breaking over us. But what a noble spectacle, had we not been exposed to danger! Let the reader imagine to himself a sheet of silver, a quarter of a league in breadth, expanded in an instant, and shining with a vivid light. Such was the effect of these billows, two or three of which only reached us, before they broke. This was a fortunate circumstance, for they left the boat half filled with water, and one more, by rendering me a prey to the sharks, would certainly have saved me from the trouble of new modelling the work of the good M. Ozanam.

There is scarcely a sea in which the phenomenon of this light is not sometimes observed; but there are certain parts where it is much more luminous than in others. In general, it is more so in warm countries, and between the tropics, than any where else; it is remarkably luminous on the coasts of Guyana, in the environs of the Cape Verd islands, near the Maldives, and the coast of Malabar, where, according to M. Godeheu de Riville, it exhibits a spectacle very much like that above described.

A phenomenon so surprising could not fail to excite the attention of philosophers; but till lately they confined themselves to vague explanations; they ascribed it to sulphur, to nitre, and other things, of which there is not a single atom in the sea, and they then imagined that they had reasoned well.

M. Vianelli, an Italian philosopher, is the first person, it seems, who endeavoured, by the help of observation, to explain the cause of this light; and he was thence conducted to a very singular discovery. Observing that the sea water, near Chioggia, had a very luminous appearance,

and that the light was concentrated into small brilliant points, he conceived the idea of examining it with a microscope. By these means he found that those luminous points were small insects, resembling worms, or rather caterpillars, composed of twelve articulations; that they differed from our luminous worms in this respect, that the light proceeded from every part of their bodies, and that when at perfect rest the light ceased, but that it re-appeared when they were put into a state of agitation. This explains why certain parts are made to sparkle by the strokes of an oar, the dashing of water against the rudder, and the breaking of the waves, while the rest of the water remains dark. These observations were confirmed by the Abbé Nollet, who soon after undertook a tour to Italy.

It appears however, that the insect which gives a luminous appearance to the water of the sea, is not every where the same. M. Godeheu de Riville, having observed some of these luminous points in the Indian seas, between the Maldives and the coast of Malabar, saw an insect quite different from Vianelli's worm with twelve rings. This insect has a near resemblance to that called the water flea, and is inclosed between two transparent shells, somewhat like a kidney half open. The luminous matter seems to be contained in a vessel, which may be compared to a bunch of grapes; it consists of small round grains, and when the insect is pressed, it emits a luminous liquor. It then mixes with the water, and, as it is of an oily nature, it collects itself on its surface in the form of small round drops. According to every appearance, the insect suffers this phosphoric liquor to escape only in consequence of some shock or agitation, or of other circumstances; and hence the reason why the sea is not luminous except when agitated, and at certain times more than others*.

* See *Mémoires des Sçavans étrangers, vol. III.*

M. Rigault observed, in the seas between Europe and merica, another insect, different from the worm of ianelli, or the water flea of M. Godeheu, being rather a ind of polype, almost spherical, and with only one arm.

In the last place, M. Leroy, a physician of Montpellier, bserved in sea water globules of a phosphoric matter, on which he made different experiments, to ascertain what ircumstance rendered them luminous, and by what means hey were deprived of that quality. From these experiments he was induced to conclude, that though Vianelli nd others have, on good grounds, ascribed the luminous ppearance of the sea to insects, or to a liquor which they ontain, and which they emit on certain occasions, this is not the only cause; but that it may arise also from a phosphoric matter in the water of the sea, and which is roduced there by a peculiar combination of the principles lispersed throughout it; that this matter is not always uminous, but becomes so from different causes, such as the shock of the particles of the water against each other, the contact of the air, and its mixture with certain liquors*.

§ II. *Of some Luminous Insects.*

If those beings which we tread under foot hold a very low, and, we might even say, contemptible rank, in the animal kingdom; nature, which seems to observe a general system of compensation, has given to several of them properties very extraordinary, and for which the largest animals might envy them: such is that of emitting light, with which many of them are endowed. We are acquainted indeed with no large animal, which enjoys it while living; but there are several insects which are luminous, and it appears that they can become so at pleasure. Of what utility is this light to them, and how is it

* See *Mémoires des Sçavans étrangers.*

produced? These are problems which we shall not attempt to solve; we shall only confine ourselves to facts.

1. *Of the Glow-worm.*

Every person is acquainted with this small insect, the light of which is often observed under the hedges in the fine evenings of summer.

This insect, called by the Greeks *lampyris*, and by the Latins *cicindela*, exhibits nothing remarkable in its external appearance. It has a pretty near resemblance to the ea louse, only that it is much smaller, and proportionally thinner; it is its last ring, where the anus is situated, that emits the light, by which it is distinguished from other animals of the same class. This light is of a pale greenish colour, and the animal can show or conceal it at pleasure. It is supposed that it is by this light, which is peculiar to the female, that it attracts the male: the latter has wings, and is destitute of this luminous quality. This however is rather a matter of conjecture, and is contested by Baron de Geer, a celebrated Swedish naturalist, in consequence of some observations made by him.

An insect so singular was, no doubt, worthy of being celebrated by the poets; and indeed M. Huet, bishop of Avranches, has made it the subject of a small poem, entitled *Lampyris*, which is much esteemed by those who are fond of Latin poetry. It begins in the following manner.

> *Quae nova per caecas splendescit stellula noctes*
> *Sepibus in nostris? An ab aethere lapsa sereno*
> *Astra cadunt, tacitis an captant frigora sylvis,*
> *Si quando ardentis coeperunt taedia coeli?*
> *Non ita, sed duris frustrà exercita matris*
> *Imperiis, sentes lustrat Lampyris opacos,*
> *Si fortè amissum possit reperire monile.*

The poet then feigns that the nymph Lampyris, having lost her necklace, is expelled by her mother, and that she

wanders about through the woods, searching for it by the help of a lantern. These ideas were much applauded a century ago; but we do not know whether the case be the same in the present one.

2. *Of the Fire Fly of warm climates.*

Such is the luminous insect of our climates; but the warmer countries have been more favoured by nature. Their luminous insects have wings. They are found in Italy after the Alps are crossed; and they become more frequent according as the traveller approaches the southern parts of Italy. They exhibit a very curious spectacle, during the fine nights of summer, when they are seen flying about in every direction, and one cannot move a step in a meadow without observing some of these small animals, whose route is marked by a train of light. I never enjoyed this spectacle in Italy; but I have seen it in South America.

It appears, however, that the fire flies of Italy, and those of America, are entirely different from the luminous insect of our countries. I confess, that during my residence in America I did not pay much attention to them. I was employed with occupations of greater importance; but I know, with certainty, that this insect emits light as it flies about. The part of its body which is luminous seems to be concealed by its wings, or by the covering of them, when closely applied to the body. I have never seen a good description of this insect, which has a great resemblance to a common fly.

It may be readily conceived, that these luminous insects must have inspired some persons with the hope of obtaining from them a perpetual phosphorus. Many attempts have been made for this purpose; but though the posterior part of the animal, when it is cut in two, retains its light for some time, it gradually becomes extinct; and every

effort hitherto made to retain it, has proved fruitless. Some authors indeed have proposed means for accomplishing this object; but these people were either impostors, or labouring under a deception: it is certain that their pretended means will not succeed.

3. *Of the Cucuyo of America.*

A valuable acquisition of this kind, possessed by America, is the Cucuyo. The Caribs have given this name to a large beetle, found in the islands of the Gulph of Mexico, and even in Mexico itself. Its luminous quality is seated in the eyes, and in two parts of its body covered by the sheaths of its wings. It is asserted that five or six of these beetles will afford a sufficient light to enable a person to walk in the darkest night; that the natives of the country tie them together alive, and by these means form them into a sort of necklaces, to guide them through the woods, and that they employ them in their huts to give them light to perform their nocturnal labours. But this we can hardly believe.

4. *Of the Beetle of Guyana.*

A luminous insect, which had a great resemblance to the Cucuyo, and which perhaps was the same, was some years ago brought to France by a very singular accident. A great deal of wood for cabinet makers having been imported from Cayenne, in 1764, and the following years, a cabinet maker purchased a piece of it, and kept it by him till he should find use for it. His wife hearing some noise one night, like the buzzing of an insect when flying, observed soon after a strong light adhering to the window. Recovering from the terror which this spectacle at first inspired, she ran up to it, and found an insect of the coleoptera kind, that is, insects whose wings are covered by a sheath, which emitted from the posterior parts of its

body a bright light that illuminated the whole apartment. The insect was put into the hands of M. Fougeroux, who wrote a description of it, which was inserted in the Memoirs of the Academy of Sciences for 1766.

There is great reason to think, or rather it is certain, that the animal had been brought over in the piece of wood in the state of nymph, concealed in some hole; the time of its developement being arrived, it issued from its retreat, and appeared under the form of a beetle.

If this insect was not the Cucuyo of the American isles, or of New Spain, it must be considered as a fourth kind endowed with the property of emitting light.

§. III. *Of some other Phosphoric Bodies.*

We shall here take a cursory view of a great number of other phosphoric bodies.

1. *The eyes of different animals.*

As several animals, such as the tiger, and the cat, which is only a tiger in miniature, the wolf, the fox, &c, among quadrupeds, and the owl, and others among birds, have been destined by nature to search for their food in the night time, it was necessary they should have a lamp to guide them. This lamp is contained in their own eyes; for they are luminous, and it is no doubt by this light that they are guided in the dark. As their retina is exceedingly sensible, the light of their eyes renders objects to them sufficiently luminous. Besides, nature has favoured them with a very large aperture in the pupil, so that the quantity of light which reaches the retina is increased. Such, in all probability, is the mechanism by which these animals see in the night time: the extreme sensibility of their retina renders the light of the day incommodious to them, and even blinds some of them.

It appears that these animals have it in their power to

render their eyes luminous at pleasure. I have often seen those of a cat, which I kept, entirely destitute of light, while at other times they were like a burning coal.

The dog also is endowed in some measure with the same property. I have several times seen the eyes of that animal sparkle.

In short, it is asserted, that some men also are endowed with this property. Tiberius, it is said, could see in the night time; and the same thing is related of many others. The most singular instance of this faculty is that of a hermit, who, according to Moschus, in his *Pré Spirituel*, had never occasion for a lamp while reading at night, or employed with any other occupation. Those who could believe such ridiculous tales would almost deserve to be sent to feed *cum asinis et jumentis*.

2. *Clayton's Diamond.*

This diamond was much celebrated; and if it was not one of the finest of its kind, this defect was more than compensated by the singular property it possessed. When rubbed in the dark against any dry stuff, or against the fingers, it shone with a faint whitish light. The celebrated Boyle made a great many observations on this diamond, an account of which he communicated to the Royal Society, in 1668; and he does not hesitate to call it a precious stone, unique of its kind; *gemma sui generis unica;* for at that time no other was known which possessed the same property. We have however heard that, since that time, other diamonds have been found, which could be rendered brilliant in the dark by friction. This singular diamond was purchased by Charles II.

We shall here say a few words respecting the carbuncle, which, as some pretend, shines also in the dark; but we must observe, that this property ascribed to it is absolutely fabulous. The carbuncle is a ruby; but no ruby,

nor any other kind of precious stone, shines in the dark; and this supposed phenomenon is merely a popular tale.

We may remark also that this light is not properly phosphoric, but is of the same nature as electric light. The diamond indeed is susceptible of becoming electric by friction; its light is of the same nature as that emitted by sugar when grated, and by various other bodies when rubbed.

3. *Rotten Wood.*

It is not uncommon to find, in the forests, pieces of rotten wood, which emit a very vivid light of a white colour, inclining to blue: it has even sometimes happened that this light has been the occasion of great terror.

Unfortunately, every kind of rotten wood is not phosphoric; and the cause which renders it so is not known.

We must class also among the number of puerile tales what is related by Josephus, of a plant called *Baaras*, said to be luminous in the dark. This plant, it is said, cannot be plucked up without the most imminent danger; but when the root of the plant has been loosened, a dog is tied to it, and the animal, by making efforts to join its master, at length tears it up. Is it possible that authors can thus sport with the credulity of mankind!

We must place in the same rank what is related by Pliny, of another plant, called *Nyctegretum*, which grows, it is said, in Gedrosia, and which when torn up by the root, and dried in the sun's rays for a month, becomes luminous in the night time. This is not absolutely impossible; but if so, the plant would be known to our naturalists, as well as the *Aglao-phytis*, and the *Lunaris*, to which the same property was ascribed, according to the testimony of Ælian. When a circumstance is related by Ælian, one may bet a hundred to one that it is a fable.

4. *The Worms in Oysters.*

This natural phosphorus was first remarked by M. de la Voye, who communicated his discovery to M. Auzout, in 1666.

Small oblong worms, which shine in the dark, are often engendered in oysters. According to the description given of them, some are as large as a small hair pin, and about five or six lines in length: others are much smaller. He found also three kinds; the first with legs to the number of about twenty-five, on each side: the second kind were red, and similar, except in size, to our common glow worms; the third were of a singular form, having a head like that of the sole. They readily resolve, on the least touch, into a viscid matter, which retains its luminous property for about twenty seconds.

Such are the observations of M. de la Voye, which do not entirely agree with those of M. Auzout, who observed only a viscid matter, extended in length. But it is to be remarked, that the latter made his experiments only on old oysters; whereas the former made his on oysters quite fresh.

5. *Putrid Flesh.*

Putrid flesh is also susceptible of becoming sometimes luminous in the dark. Lemery says that a great quantity of such luminous flesh was seen at Orleans, in 1696; some of it was entirely so; other pieces were luminous only in some points, which had the appearance of small stars. People were at first afraid to eat of it; but they soon learned by experience that there was no danger, and that it was as good as any other. It was remarked that in some butchers' shops the meat was almost all luminous; in others only part of it was so.

Fabricius ab Aquapendente relates the same thing of a

lamb, purchased by some young men at Rome. One half of it, which was left, being put by, they observed in the evening that several parts of it were luminous. They immediately sent for the above physician, who having examined the phenomenon with attention, observed that the flesh and the fat shone with a silver coloured light; and that a piece of goat's flesh, which had touched the lamb, shone in the same manner. The fingers of those who touched it became luminous also. He observed likewise that the luminous places were softer. This phenomenon would, no doubt, be observed more frequently, if the butchers' shops, and places where meat are kept, were oftener visited in the dark.

6. *Different kinds of Fish, or the Parts of Fish.*

But this phenomenon is most frequently exhibited by fish, and their different parts.

It is generally when fish, or any of their parts, approach the state of putrefaction, that they acquire this phosphoric property. Leo Allatius, in a letter to Fortunio Liceti, says that he was once much frightened by fresh water crabs thrown into a corner by a careless servant. He describes the whole of this adventure at great length; but want of room will not permit us to enter into any farther details respecting it.

According to Pliny, and other authors, the sea worm is susceptible of shining in this manner. Those who reside near the sea coast may have an opportunity of ascertaining the truth of this fact.

The celebrated Thomas Bartholin observed the same thing, in regard to some polypes, which he was dissecting: he gives this name to the fish called at present the cuttle fish, since he says that it contains a black liquor, which may be employed as ink. This light, adds he, flowed

from beneath the skin, and was the more abundant the nearer the animal approached to a state of putrefaction.

We shall conclude this subject by mentioning some experiments of Dr. Beale, inserted in the Philosophical Transactions, for the year 1666. Fresh mackarels having been boiled in water with salt and herbs, the cook stirring the water a few days after, to take out some of the fish, observed that on the first movement of the water it became luminous, as well as the fish, which emitted a strong light through it: the water also appeared to be transparent; whereas in the day time it was opake.

Drops of this water were exceedingly luminous; and wherever they fell, they left a luminous spot, as large as a sixpence. On rubbing the hands with it, they became entirely luminous.

We have here confined ourselves to facts; for nothing farther can be said on the subject, as it is difficult to assign any probable or well founded cause for this light. The globulous matter of Descartes was exceedingly convenient for explaining all these phenomena; for it was sufficient to say, that putrid fermentation, being a kind of intestine motion, this motion, according to every appearance, put in action the globulous matter in which light consists. But unfortunately this matter, at present, is considered as a chimera.

ADDITION BY THE FRENCH CENSOR.

There are some inaccuracies in what has been before said in regard to the luminous insects, in the 1st, 2d, 3d, and 4th paragraphs of the second section. The author seems to have trusted too much to his memory, which has led him into error, and not to have been acquainted with every thing written on the subject. We shall therefore supply this deficiency.

1st. The male of the glow worm is a winged insect of the class of the coleoptera, or insects which have sheaths to their wings. It is not entirely destitute of the property of being luminous. M. Fougeroux says, that he often caught in the dark some of these males, which were attracted by the light of the female, and he observed that they emitted light themselves after copulation.

2d. The fire fly of Italy, commonly known under the name of the *lucciola*, is not a fly; it is also an insect with sheaths to its wings, and in form approaches near to the male of the glow worm. At first one might be induced to believe that it is the same insect, to which the climate has given the property of shining in the dark, as is the case with that of our country under certain circumstances. But there are some differences, which will not allow of their being confounded; and what seems absolutely to exclude this identity is, that in places where the *lucciola* is found the common glow worm is never seen, though it exists also in Italy.

In regard to the luminous insect of the warm countries of America, I must remark, with the author, that I am unacquainted with any correct description of it.

3d. What has been said, in regard to the luminous insect of Cayenne, is not entirely correct; and the account given of its being discovered requires to be rectified. In the month of September, 1766, two women, in the *Faubourg Saint-Antoine*, saw this insect in the evening flying through the air, like a stream of light, and at length settle on a window. They at first thought that it was one of those falling stars so common during the summer nights; but as the light continued, they went to inform the occupiers of the house against which the animal rested. It was caught, and given to M. Fougeroux, in order that he might examine it. That it came from Cayenne was only conjecture; but by comparing it with the insects of that

country, it appeared to be an inhabitant of the same or a neighbouring climate. It was a coleoptera, known under the name of *mareschal,* and of the class of those which, when placed on their back, dart into the air like a spring which unbends itself: on this account it has been distinguished by the name of *elater.* This insect is an inch and a half in length; its light is contained in two elongated protuberances, placed on the posterior and lateral part of its corselet. It emits light also in certain positions, by the separation of its body from the corselet; and in all probability by that of the rings of its body from each other. This light is of a beautiful green colour, and of such strength that if the insect be put into a paper cornet, one can see to read the smallest characters by it, at the distance of some inches. This insect is found also in Jamaica, and has been described by Brown, under the denomination of *elater major fuscus phosphoricus.* Another smaller kind of phosphoric fly is found in Jamaica, and also in Saint Domingo.

4th. What the author says of the *cucuyo* of America, that it emits light from its eyes and two parts above the sheaths of its wings, is not correct. It is possible that travellers, unacquainted with natural history, who have spoken of it, may not have examined it with attention.

5th. There are some other luminous insects, which the author has not mentioned. The lantern-bearer or *acudia,* which Reaumur places in the class of the *pro-cigales,* (cicada spumaria,) or a class which approaches near to that of the *cigales,* (grasshopper,) the *vielleur* beetle of Surinam; like the author, we are unacquainted with any description, sufficiently correct, to enable us to determine in what they differ from the *cucuyo,* and from each other. Such also is the lantern-bearer of China, described by Linnæus, in the Transactions of the Academy of Stockholm; but as the animal was dead, that learned naturalist

had no opportunity of ascertaining what part of it is luminous; he suspects it is the proboscis, which does not appear improbable. There is also an insect of the same kind in Madagascar, known under the name of *hesecherche*, which shines in the night-time. But we have never seen a description of it.

6th. Clayton's diamond was long considered to be the only one which had the property of shining in the dark. But M. Dufay found, by a great number of experiments made on different diamonds, that several of them possessed the same property; though he was not able to discover the cause, why some of them possessed it, while others were destitute of it. Beccari, a celebrated philosopher of Bologna, made at the same time similar experiments, which confirm the discovery of Dufay. This philosopher found that the class of phosphoric bodies is much more considerable than is commonly supposed; and it follows from his experiments, that the phosphoric bodies which have chiefly attracted the attention of philosophers, did so, not on account of that property maintaining itself for a longer time, but because a very great number of bodies appear luminous to an eye immersed in profound obscurity, when they are speedily removed from the light to a place of darkness.

7th. The sea worms or borers possess this property in an eminent degree; not when they approach to a state of putrefaction, as has been before said, but when living and fresh, so as to be fit for eating. The observations of Beccari, Monti, and Calcati of Bologna, on these marine fish, are very old; and they confirm and illustrate what has been said by Pliny on the same subject*.

* See a Memoir of M. de Reaumur on the same subject. *Mém. de l'Acad.* 1723.

ARTICLE II.

Artificial kinds of Phosphorus.

What nature produces under certain circumstances, art assisted by observation has found means to imitate, in the artificial kinds of phosphorus. But before we explain these curious operations, we must make a distinction which the modern chemists have introduced, and which is necessary.

The appellation *phosphorus* is still given to those bodies which emit light without any sensible heat; but when a body emits light, and at the same time inflames of itself, when exposed to the air, it is called *pyrophorus.* Hence we say the pyrophorus of Homberg, to denote that composition of alum and animal or vegetable matter which takes fire when exposed to the air. The English phosphorus is both phosphorus and pyrophorus; for when exposed to the air in a mass, it burns, and consumes like sulphur, of which it is a singular species, but very much attenuated; and when mixed with a liquor, it becomes luminous, without heat.

§. 1. *Phosphoric experiment: or how to burn gunpowder without an explosion.*

Expose a towel or cloth to a strong heat, till it becomes very hot, and carry it into a dark place. While it is cooling, throw upon it, from time to time, some grains of gunpowder, which at first will inflame. Leave it to cool a little, till the powder no longer detonates. If you then cover it with powder, the latter, when it acquires the same heat as the cloth, will emit in the dark a faint light or weak flame, which will consume all the sulphur, without causing the nitre to detonate.

It is hence seen, that common sulphur is susceptible of two combustions, one gentle and calm, which is not capable

even of kindling the charcoal, otherwise the nitre would detonate; and the other violent, which burns and kindles such combustible bodies as are in contact with it.

§ 11. *Of the Bologna Stone.*

This kind of phosphorus is called the Bologna stone, because first made from a stone found only at the bottom of mount Paterno, near that city. A shoemaker, named Vincenzo Casciarolo, was the first who observed the property which these stones have of shining in the dark, after they have been calcined. He was employed on the *grand work*, as it was called, and from the brilliant appearance of these stones, he conceived an idea that they contained either metals, or some principle by which he should obtain what he was in quest of. He therefore brought them to a red heat in a crucible, and having afterwards carried them into a dark place, he was struck by their luminous appearance, and published an account of his discovery. This phosphorus is made by the modern chemists in the following manner.

They take one of these stones, and having freed it from all its heterogeneous parts, file it all round with a large file, in order to obtain a certain quantity of dust. They then dip the stone in the white of an egg, and roll it in the dust, until it be entirely covered with it to a certain depth. When the stone is dry, it is placed in a furnace filled with charcoal, in such a manner, as to be completely surrounded by it. The charcoal is then kindled, and when the whole is consumed, the stone is found calcined according to the required degree. If it be carried into a dark place, it will be seen to shine with a singular brilliancy, which however becomes gradually weaker, and after some minutes entirely ceases. But this brightness may be renewed by exposing the stone for some time to the day-light. These stones are preserved in a dry place, wrapped up in dry cotton.

They however gradually lose their property of imbibing the light; but it may be restored to them by a second calcination.

The Bologna stone, according to the observations made by naturalists, is one of those known under the name of *fusible spar*. Vitriolic acid enters into their composition, and this inspired Margraf, a celebrated chemist, with the idea of trying whether all the other spars were not endowed with the same property. He found that when treated in a proper manner, they all become luminous. The process for calcining and preparing them, according to his method, is as follows.

When properly freed from their heterogeneous parts, they are brought to a red heat in a crucible, and then reduced to very fine powder in a glass or porphyry morter. This powder is formed into small cakes, a line or more in thickness, and of any size at pleasure, by mixing it with gum tragacanth and the white of an egg, and these cakes are then calcined in the following manner, after they have been dried in a strong heat.

A common reverberating furnace is filled to three fourths of its height with charcoal; the cakes are laid flat above it, and are covered with more charcoal. The furnace is then kindled, and when the whole charcoal is consumed, and the furnace has cooled, the cakes are found calcined. After being cleaned from the ashes, by means of a pair of bellows, they are preserved for use, as before described. When an experiment is to be made, they are exposed for some time to the light, after which they are carried into a dark place, where they exhibit the appearance of burning coals, to those who have kept their eyes shut for a few minutes.

The most probable cause of this phenomenon, according to the ablest chemists, is as follows:

When it is considered that phosphorus of the same kind

is made only by burning, with charcoal, stones which contain vitriolic acid*, there is reason to think that in this operation there is formed a kind of sulphur, exceedingly combustible, and in which the action of the light alone is capable of producing that slow combustion, almost without heat, of which common sulphur, as already seen, is itself susceptible. This combustion manifests itself only by the faint light it emits. It ceases with the absence of the cause which produced it; and the stone no longer is luminous.

Among several reasons which confirm this explanation, there is one, which seems to be of great weight: after the stone has ceased to shine, if placed in a dark place on a plate of iron, which has been heated, but not to such a degree as to emit light, it immediately becomes luminous, without having been exposed to the action of the sun's light. To this reason we may also add, the odour exhaled by the Bologna stone; for it is exactly the same as that of sulphur. But, in regard to this subject, we must refer the reader to Macquer's *Dictionnaire de Chimie*, under the head stony phosphorus, where explanations will be found, which, on account of their length, cannot be admitted into this work.

§ III. *Baldwin's Phosphorus.*

This phosphorus, as well as the following, has a great affinity to the Bologna stone. The method of making it is as follows:

Dissolve very pure white chalk in good spirit of nitre; filter the solution, and evaporate the liquor till the residuum is very dry. Then put the residuum into a good crucible of a proper size, and place it for an hour in a reverberat-

* Margraf at least asserts so, though Dufay says he made Bologna phosphorus with stones purely calcareous.

ing furnace. If the matter calcined in this manner be put into a bottle, with a glass stopper, you will have Baldwin's phosphorus.

This phosphorus has the property of shining in the dark, like the Bologna stone, if the bottle containing it be exposed open to the light. But as it has the fault of attracting moisture, it soon loses this property.

§ IV. *Homberg's Phosphorus.*

Take one part of sal ammoniac in powder, and two parts of quick-lime slaked in the open air; mix them well together; and having filled a crucible with the mixture, place it over a slow fire. As soon as the crucible is red, the mixture will begin to fuse; but as it rises up and swells in the crucible, it must be stirred with an iron rod, to prevent it from running over. When the matter is fused, pour it into a copper bason, and when cool it will appear of a grey colour, and as if vitrified. If it be struck with any thing hard, such as a piece of iron, copper, or other substance of the like kind, the whole part which has been struck will for a moment seem on fire. But as this matter is very brittle, the experiment cannot be often repeated. To remedy this defect, M. Homberg immersed in the crucible, containing the fused matter, small rods of iron or copper, which by these means became covered with it as with enamel. The experiment may be performed on rods incrusted in this manner, as they will bear to be struck several times, without the matter being deranged.

It is to be observed that the phosphoric enamel, which adheres to these rods, readily attracts the moisture of the air: for this reason they must be deposited in a dry warm place, where they will retain their property for a long time.

§ v. *Canton's Phosphorus, or Phosphorus in Powder.*

Another kind of phosphorus, analogous to that of Baldwin, and to the Bologna stone, may be made in the following manner:

Calcine oyster shells, by keeping them in a common fire for half an hour, and then pulverize them; mix the finest part of this powder with one third of its weight of fine flour of sulphur, and put the mixture in a crucible, filling it to the brim, and keep it for half an hour at least in the midst of burning coals, till it is perfectly red. Then suffer it to cool, and having once more pulverized the matter it contains, if necessary, you will obtain a phosphorus, which, if exposed for a few minutes to the day-light, will appear luminous in the dark.

Those who have comprehended the nature of the Bologna phosphorus will readily see that Canton's phosphorus is properly the same thing: for the Bologna stone and all the fusible spars, which have been found to possess a phosphoric property, are nothing but combinations of vitriolic acid with calcareous earths.

§ vi. *Homberg's Pyrophorus.*

The following chemical discovery was entirely owing to chance. The celebrated Homberg had been assured that a white oil, in no manner fetid, which had the property of fixing mercury, could be extracted from human excrement. He therefore subjected this matter to experiment; and extracted from it a white oil without any odour. It did not fix mercury; but having exposed the residuum of his distillation to the air, he was surprised to see it take fire. Such is the origin of his pyrophorus.

It has however been since found, that it is not necessary to employ matters so filthy as those from which Homberg

first extracted this pyrophorus. The common process for this purpose is simple, and is as follows:

Mix in an iron pan, placed over the fire, by means of an iron spatula, three parts of alum and one of sugar, until the matter becomes perfectly dry, and reduced to a blackish carbonaceous substance: if there be any lumps in it of considerable size, they must be broken. Put this matter into a matrass with a narrow neck, about eight inches in length, and place the matrass in a crucible, capable of containing the belly of it when surrounded by half an inch of sand. Then immerse the crucible in burning coals, and bring both it and the matrass to a state of ignition, heating it at first gradually, and then strongly urging the fire, till a sulphurous flame is seen to issue from the neck of the matrass. The fire must be maintained in this state for about a quarter of an hour; then suffer the fire to become gradually extinct, and when the neck of the matrass is no longer red, close it with a cork stopper, otherwise the pyrophorus would inflame.

When the whole is perfectly cold, pour the pyrophorus speedily into several phials, which can be well shut, and instantly close them. Sometimes it inflames in passing from the matrass to the bottle; but this is of no consequence, as it is extinguished as soon as the bottle is closed.

To make an experiment with pyrophorus, put a small quantity of it on a piece of paper. Soon after, it inflames, becomes red like a burning coal, and sets fire to any combustible bodies it may be in contact with. The inflammation may be accelerated by putting it on paper somewhat moist, and breathing upon it.

§ VII. *Of the Phosphorus or Pyrophorus of Kunkel, called also the English phosphorus.*

This is the most curious composition of the modern

chemistry. Who would have believed that a luminous body could be extracted from putrid urine? Nay more, a body susceptible of inflammation, and capable of inflaming, by its contact, other combustible bodies? Such however is the origin of this phosphorus, which in some measure may be considered as abject; but, to the philosopher, nothing is abject in nature, and the most disgusting objects sometimes contain principles, capable of producing the most singular and uncommon effects.

The discovery of the phosphorus of urine, like many others, was the effect of chance. A citizen of Hamburgh, an enthusiast in regard to the philosopher's stone, was making some experiments with urine. He was not the first nor the only person who imagined that the substance proper for fixing mercury ought to be found in human excrement; and by repeated trials, on this matter, he found phosphorus. This discovery made a great noise in the chemical world. But Brandt, the author of it, was not disposed to part with his secret for nothing. Kunckel, an able chemist, united with one Krafft to endeavour to draw from him the process; but Krafft deceived Kunckel, purchased from Brandt the secret of making this phosphorus, and being desirous to carry on a lucrative traffic, refused to impart it to his associate. The latter incensed on account of this treachery of Krafft, and knowing that he had made great use of human urine, endeavoured by researches to discover the secret, and at length found it. The honour of it therefore has remained with him; for this phosphorus is commonly called *Kunckel's Phosphorus**.

On the other hand, Krafft went to England, and having shown his phosphorus to the king and queen, the celebrated

* Leibnitz asserts that this account, generally given in regard to Brandt, is entirely void of foundation. He gives a history of phosphorus, which may be seen in his works, vol. II.

Boyle, whose curiosity was highly excited by so singular a phenomenon, endeavoured also to discover the secret. He knew only, like Kunckel, that Krafft laboured on urine. He began therefore to make experiments on that matter, and found out likewise the method of extracting phosphorus from it. He communicated the process to the public, in the Philosophical Transactions for 1680, and according to every appearance taught the different operations more particularly to a German chemist, settled at London, named Godfreyd Hanckwitz; for he was a long time the only person who made phosphorus.

Though Boyle published the process for making this phosphorus, in 1680; though Homberg taught it in 1692; and though described in various books, phosphorus was made only in England, and by Hanckwitz alone. A foreigner, who came to France in 1737, offered however to disclose the whole process, and the ministry promised him a reward for it. Several chemists and members of the Royal Academy of Sciences were requested to be present at the operation, which was performed at the *Jardin Royal des Plantes*, and attended with perfect success. M. Hellot wrote an account of the process, and published it in 1738, in the Memoirs of the Royal Academy of Sciences. Since that time only the method of making phosphorus has been known; but it is one of the nicest operations of chemistry, and does not succeed but in very expert hands.

But none of the modern chemists has paid so much attention to the composition of phosphorus as Margraf, who has rendered the process more certain, more exact, and less tedious; for this reason we shall take him as our guide, in what we are going to say on this subject.

1st. Provide good urine, and let it purify itself; then put it into a glass vessel, placed over the fire, and evaporate the phlegm, till it be reduced to the consistence of honey or of cream.

It must here be observed that this matter contains a particular salt, called *fusible salt of urine*; that this salt is composed of an acid different from all the rest, called the *phosphoric*, because it is a necessary ingredient in phosphorus, by its combination with another principle, and because this acid is extracted by the deflagration of phosphorus, as the vitriolic acid is by that of common sulphur.

2d. Then mix four pounds of minium with two pounds of sal ammoniac in powder, and distil the mixture, which will furnish a volatile alkali highly concentrated. This alkali however is useless. But marine acid will attack the minium or calx of lead, and will form with it a compound, known to chemists under the name of *corneous lead.* Corneous lead, ready made, may be employed; but we have thought proper to describe the method of making it, because all our readers may not be chemists.

3d. Mix this corneous lead, by little and little, in an iron pan, with eight or nine pounds of the extract of urine, mentioned in the 1st article, taking care to stir it continually; add to it half a pound of charcoal dust, and continue to dry it till it be reduced to a black powder. Then throw the matter into a retort to distil it in a moderate heat, and extract from it all the products; which are volatile alkali, a fetid oil, and a kind of sal ammoniac, which adheres to the neck of the vessel. Then bring the retort to a moderate red heat, and when nothing more passes over, unlute the apparatus, and reserve the residuum, which is a kind of *caput mortuum.* This residuum contains the phosphorus, and must be distilled in a much more violent heat. It is a sign that it is well prepared, if a small bit of it, when thrown on the coals, exhales an odour of garlic, and burns with a small lambent flame.

4th. Put the residuum into a good Hessian retort. M. Margraf recommends those of Waldenbourg as the best; but none of them are brought to France. Those of Hesse

over them a little of this oil, which has no sensible heat, because the phosphoric fire is very much rarefied.

This phosphorus amalgamates very well with mercury, and forms a luminous compound. Put ten grains of phosphorus into a pretty large long phial, with two ounces of oil of lavender. The phosphorus will dissolve in it, provided it be exposed to a gentle heat. If you then add half a dram of quicksilver, you will obtain an amalgam, which will be entirely luminous in the dark.

For the same purpose, phosphorus may be mixed with pomatum: it will become luminous, and may be rubbed over the face and hands without any danger.

§ VIII. *Composition of a kind of a pyrophorus, which emits flames when brought into contact with a drop of water.*

For this composition we are indebted to the celebrated chemist Glauber. Mix together iron-filings, cadmia, tartar, and nitre; then form them into a paste, and dry it well in a strong heat, such as that of a potter's furnace. If a few drops of water be thrown over this mass, it will emit flames and sparks. Such is the description given of this process by Beccher. The following is another, extracted from the *Natural Magic* of Martius. Pulverize quick-lime, tutty, and storax calamite, each an ounce; live sulphur and camphor each two ounces; and having mixed them well together and sifted them, wrap them up in a piece of very thick linen cloth. Put this cloth into a crucible, cover it with another crucible, which must be tied closely to the former, and lute the joining with potters earth. When the luting is perfectly dry, put this double crucible into a potter's furnace, and leave it there till the matter is entirely calcined. This may be known by the colour of the crucibles, which ought to be of a pale red: when the whole is cool, if you throw a drop of water or spirit on this matter, it will emit sparks.

It was no doubt by means of a similar composition, that a German Jew drew sparks from the head of his cane, by spitting on it. This invention indeed is very proper for being employed by jugglers, to excite the wonder of the populace, and extort money from them. The Jew, here alluded to, it seems, turned to great advantage this chemical secret.

Remark.—There are some other pretended kinds of phosphorus; but properly speaking they are not so: they are merely electric phenomena.

Of this kind is the light seen in the inside of certain barometers, called for this reason *luminous*. In the old editions of the Mathematical Recreations, it was called *Dutal's Phosphorus*, because that physician, but after Bernoulli, was able to make luminous barometers; it is however now known that this does not arise from phosphorus, but is merely an electric light. M. Ludolff, a German philosopher, has clearly proved, that this phenomenon is the effect of electricity, produced in the tube of the barometer by the friction of the mercury.

The case is nearly the same with mercury, which becomes luminous when inclosed in a very clear glass vessel, exhausted of air. We have described this phenomenon in the commencement of the present volume: it is also an electric phenomenon.

The light emitted by a diamond rubbed in the dark, or a bit of sugar when grated, is of the same kind.

SUPPLEMENT II.

Perpetual Lamps.

THE subject of perpetual lamps has too intimate a connection with that of phosphorus to be here omitted; for if we were urged to explain the accounts given of fire found in the tombs of the ancients, and from which some pretend to conclude they were acquainted with the art of maintaining a lamp lighted for ages, it would be necessary to have recourse to phosphorus. But these facts rest on so slight a foundation, some of them even bear such evident marks of fiction, and the greater part of those which the honest Fortunio Liceti, a strong partizan of perpetual lamps, has collected as proof of this discovery, are so evident proofs of the contrary, that a moderate degree of acuteness is sufficient to show that nothing is less entitled to credit. If to this be added the physical reasons which contradict the possibility of an inflammable liquor, burning continually without being consumed, the perpetual lamps must be considered as a chimera, unworthy the attention of a philosopher, and fit only to be banished to the country of potable gold and palingenesy. If we introduce them therefore into this work, it is merely on account of the celebrity of the subject, and because we know that some persons are fond of these singular and extraordinary tales.

ARTICLE I.

Examination of the facts alleged as a proof of the existence of perpetual lamps.

Before the improved state of philosophy had shown the impossibility of real un-extinguishable fire, the learned were much divided in their opinions on this subject;

but of all the champions in favour of perpetual lamps, none has made greater efforts to obtain credit to their existence than Fortunio Liceti, in his book entitled *De Reconditis Antiquorum Lucernis.*

If credit may be given to this author, nothing was more common among the ancients than perpetual lamps. The lamp of Demosthenes, that which burnt in the temple of Minerva at Athens, the vestal fire at Rome, all furnish him with so many proofs of the possibility of un-extinguishable fire. We cannot help smiling to see so much learning so idly employed: for who does not know that these fires were called perpetual, merely because it was a point of religion to preserve them from being extinguished, and to supply them with continual aliment?

The other partisans of perpetual lamps, while they smile at the simplicity of Liceti, support their reasoning on facts, which seem to carry with them a little more weight; they are as follow.

1. *The Lamp of Tulliola.*

The tomb of Tulliola, the beloved daughter of Cicero, and whose death cost him so many tears, was discovered, it is said, under the pontificate of Pius III. It is pretended that in this tomb there was a lamp actually burning, but which became extinguished on the admission of air.

2. *The Lamp of Olybius.*

But it is the lamp of Olybius, which, above all others, supplies the partisans of perpetual lamps with one of their strongest arguments.

In the year 1500, as we are told, some peasants digging the earth to a considerable depth at Atesta, in the neighbourhood of Padua, came to a tomb, in which they found two earthen urns, one within the other. The inner, it is said, contained a burning lamp, placed between two phials,

one filled with liquid gold, and the other with liquid silver. On the large urn was the following inscription.

> Plutoni sacrum munus ne attingite, fures;
> Ignotum est vobis hoc quod in orbe latet;
> Namque elementa gravi clausit digesta labore,
> Vase sub hoc modico, maximus Olybius.
> Adsit fecundo custos sibi copia cornu,
> Ne tanti pretium depereat laticis.

The second is said to have been inscribed also with these lines:

> Abite hinc, pessimi fures;
> Vos quid vultis vestris cum occulis emissitiis?
> Abite hinc vestro cum Mercurio
> Petasato caduceatoque.
> Maximus maximum donum Plutoni hoc sacrum fecit.

Such is the manner in which this curious discovery is related by Gesner. But what follows is still stronger. Liceti gives a letter of one Maturantius, who tells his friend Alphenus, that he had got possession of this valuable treasure. " Both the vases," says he, " with the inscriptions, the lamp and the phials, have fallen into my hands, and are now in my possession. If you saw them you would be astonished. I would not part with them for a thousand crowns of gold." This is no doubt the language of a man who believes he possesses an inestimable rarity. We do not however know that it exists in any collection.

It appears that in this case, as in regard to the tomb of Tulliola, an accident prevented enlightened people from being witnesses to the phenomenon; for we read in the credulous Porta, that as the peasants who found this treasure handled it too roughly, the lamp broke in their hands, and was extinguished.

3. *The Lamp of Pallas, the son of Evander.*

We are told also that, about the year 800 of the Christian

æra, the tomb of the famous Pallas the son of Evander, killed as is well known by Turnus, was found at Rome.

It was known to be that of Pallas by these verses:

> Filius Evandri Pallas quem lancea Turni
> Militis occidit, more suo jacet hic.

It contained a burning lamp; which consequently must have burnt nearly 2000 years, since it was shut up in the year 1170 before the Christian æra.

4. *The Lamp in the Temple of Venus.*

This lamp, and the temple of Venus, in which it was suspended, are mentioned by St. Augustine. He says it burnt perpetually, and that the flame adhered so strongly to the combustible matter, that neither wind, rain, nor tempests could extinguish it, though continually exposed to the air, and to the inclemency of the seasons. This author endeavours to explain the mechanism of it, and after offering a conjecture, which in part is pretty correct, namely, that a wick of asbestos was perhaps employed, he concludes by saying that it might have been the work of demons, in order to blind the pagans more and more, and to attach them to the infamous deity worshipped in this temple.

Here then, according to the partisans of perpetual lamps, we have un-extinguishable fire, the existence of which is fully confirmed by the testimony of the most enlightened man of his age; and who notwithstanding his knowledge, is obliged to have recourse to the artifice of demons to explain this phenomenon.

5. *Lamps of Cassiodorus.*

The celebrated Cassiodorus, who, it is well known, was as much respected on account of his employments as of his talents, tells us himself that he made perpetual lamps for

his monastery at Viviers. Each monk, it is probable, had one of them for his own use. His words are: *Paravimus etiam nocturnis vigiliis mecanicas lucernas conservatrices illuminantium flammarum, ipsas sibi nutrientes incendium, quæ humano ministerio cessante prolixe custodiant uberrimi luminis abundantissimam claritatem, ubi olei pinguedo non deficit, quamvis jugiter flammis ardentibus torreatur.* Some partisans of perpetual lamps may here say: "Is it possible to refuse credit to testimony so authentic, so clear, and so respectable?"

Such are the principal facts adduced in favour of perpetual lamps; but we may venture to say that they will not stand the test of critical examination. In regard to the first three, what dependance can be placed on facts related in so vague a manner, and accompanied with such incoherent and romantic circumstances? None of these facts are supported by any other testimony than that of men who lived a long time after; no person whose testimony is of any weight asserts that he actually saw them. But in disputes which are contrary to the common laws of nature, they must at least be certified by enlightened men, above all suspicion of credulity or ignorance.

The tale respecting the tomb of Tulliola is as old as the year 1345, a period when all Europe was sunk in the grossest ignorance. A body is said to have been found in it; and in that case it could not be the body of Tulliola, for the Romans, in the time of Cicero, always burnt their dead. In consequence of this and similar circumstances, some authors have conjectured that the tomb alluded to was that of the wife of Stilico; but the Christians never placed lamps in their tombs. The account therefore of a lamp found in this tomb has every appearance of a fiction.

But what shall we say of the tomb of Olybius, and the lamp with two phials, one filled with fluid gold, and the other with fluid silver? This double urn was found by

peasants, who according to some authors handled the lamp, contained in the second urn, so clumsily, as to break it, and yet Maturantius pretends that he had it in his possession. Who saw the lamp burning? what evidence have we that the peasants beheld it in that state? and whose testimony in this case would be admissible? Some vapour exhaled from a place shut up for so many ages might easily impose on rude and ignorant people.

What is the meaning of the inscription? where is there any allusion in it to perpetual fire? Is it necessary that a gift sacred to Pluto should be a burning lamp? If there be any truth in the discovery of this tomb, it ought only to be concluded that it belonged to some alchemist, of an age not very remote; for it is well known that the Romans had no idea of chemistry, and none of them ever attempted the transmutation of metals. If this folly had then been in existence, some traces of it would certainly be found in their writings; but on this subject they all observe the most profound silence. This chimera was communicated to us by the Arabs, with some real knowledge in regard to chemistry.

But if the Romans were unacquainted with chemistry, how could they construct perpetual lamps, which would be one of the greatest productions of that science?

The story of the tomb of Pallas, the son of Evander, is scarcely worth refutation. Who can be so weak as to believe that the verses, already quoted, were written in the time of Eneas? One needs only to have seen the language of the twelve tables, to be able to judge how little resemblance the ancient language of the Romans, and consequently that of the period of the kings of Alba, bore to these Latin verses.

In regard to the lamp of Venus, which occasioned so much difficulty to St. Augustine, we shall observe that this author does not say that it was never supplied with new

aliment. What seems to be most singular is, that it could not be extinguished, either by wind or by rain; but in this there is nothing wonderful, since our oilmen sell flambeaux which have the same property. A method of making similar fire may be found in various books of chemistry. Besides, even admitting that this lamp was perpetual and inextinguishable, who is so ignorant as not to know that the Pagan priests were the greatest impostors, and that they might employ many artifices to supply the lamp with new aliment?

The lamps of Cassiodorus may be explained with equal ease; they were lamps which, like those of Cardan, supplied themselves with oil by means of a reservoir; and Cassiodorus only meant to say, that these lamps lasted a long time, in comparison of the common lamps of that period, which stood frequently in need of having oil poured into them.

These reflections did not escape several ingenious writers, such as Aresi, a bishop, and author of *Symbola seu Emblemata sacra;* Buonamici, a philosopher contemporary with Liceti; and particularly Octavio Ferrari, to whom we are indebted for a curious and learned work *De Veterum Lucernus sepulchralibus.* All these authors, and especially the last, overturn the arguments of Liceti, and fully show that the facts he has adduced in favour of perpetual lamps rest on a weak foundation, and that they abound with absurdities and contradictions. They even ridicule the weakness of this learned man, who by an excess of credulity, almost beyond belief, finds in the lamp of the tomb of the necromancer Merlin, described by the poet Ariosto, a proof of perpetual lamps.

We shall conclude this article with the following very just reflections of Octavio Ferrari, before mentioned, which naturally suggest themselves to the mind. If the secret of constructing perpetual and inextinguishable fire had

been known to the ancients, would an art so useful have remained buried in oblivion? but, even admitting that it might be lost, for want of philosophical and chemical knowledge, is it possible that Pliny, who enumerates the common inventions, as well as those most celebrated, should say nothing of this perpetual fire, a thing so wonderful? When Plutarch makes mention of the lamp of Jupiter Ammon, because it burnt a whole year, is it to be supposed that he would observe silence respecting lamps, in comparison of which the former was a contemptible trifle?

We must therefore say, that both history and sound criticism oppose every idea of such an invention having ever existed. We shall now examine how far it is consistent with the principles of philosophy.

ARTICLE II.

On the Physical Possibility of making a Perpetual Lamp.

Having proved the weakness of all the facts brought as proofs in favour of perpetual lamps, it remains that we should examine how far they are possible, according to the principles of sound philosophy.

To obtain a perpetual lamp, it would be necessary to have as follows:

1st. A wick which could not be consumed.

2d. Some aliment which could not be consumed, or a substance which, after having served as aliment to the fire, should return into the vessel, without losing its inflammable quality.

3d. It would be necessary also that the flame should be able to exist a long time in a place absolutely close, and of small dimensions; for such were the tombs in which these perpetual lamps are said to have been found.

But all these things are impossible, as will be seen by what follows.

§ I. *Impossibility of procuring a perpetual wick. History of the amianthus; manner of spinning it, and forming it into a wick; examination of its supposed incombustibility.*

The curious properties ascribed to the amianthus, which are in part real, are well known. We shall here give the history of it; but we shall not be so prolix as the inexhaustible abbé Vallemont. The amianthus, called also *incombustible flax*, and *asbestos*, is a mineral substance found in several parts of the earth. It consists of fibres of a white colour, more or less greyish, which adhere strongly to each other. Means however are found to separate them, and when well washed, they have the appearance of the whitest flax. The amianthus is found in the Pyrenées, the Alps, &c. The most beautiful, in our opinion, is that found in or near the mine of Pesey in Savoy. We have seen some, the filaments of which were above a foot in length, and exceedingly white.

But the singular property which characterizes this substance is, that it remains unhurt in the fire, and when taken out is purer and whiter than it was before. This property therefore has been made the basis of a thousand moral and pious comparisons, which we shall not here repeat.

It is proper to observe, that the druggists, a sort of men who throw all natural history into confusion by their corrupted nomenclature, are acquainted with asbestos under no other name than that of *feathered alum:* but this denomination arises from profound ignorance. Alum is a salt, and is soluble in water, whereas the amianthus is insoluble in that liquid. The amianthus therefore is not alum. What has given occasion to this false denomination is, that there is indeed a feathered alum, or alum crystallized in fibres, which has some resemblance to the

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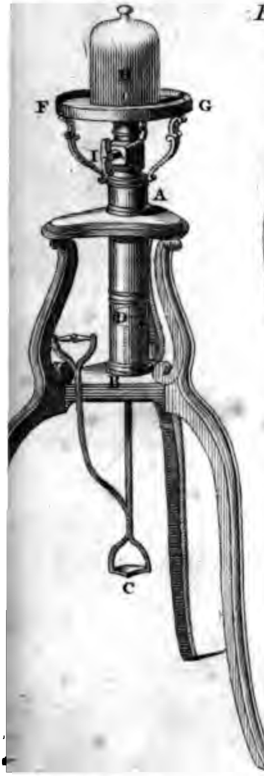

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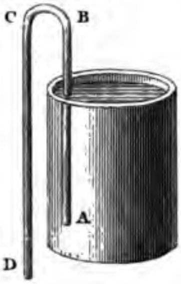

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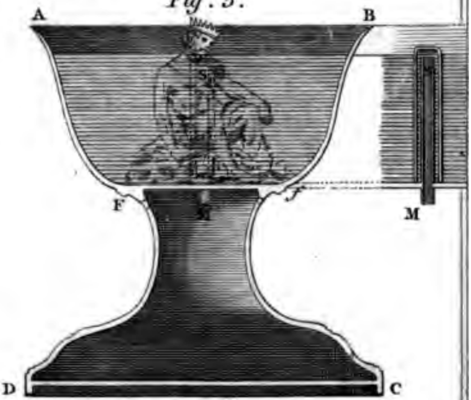

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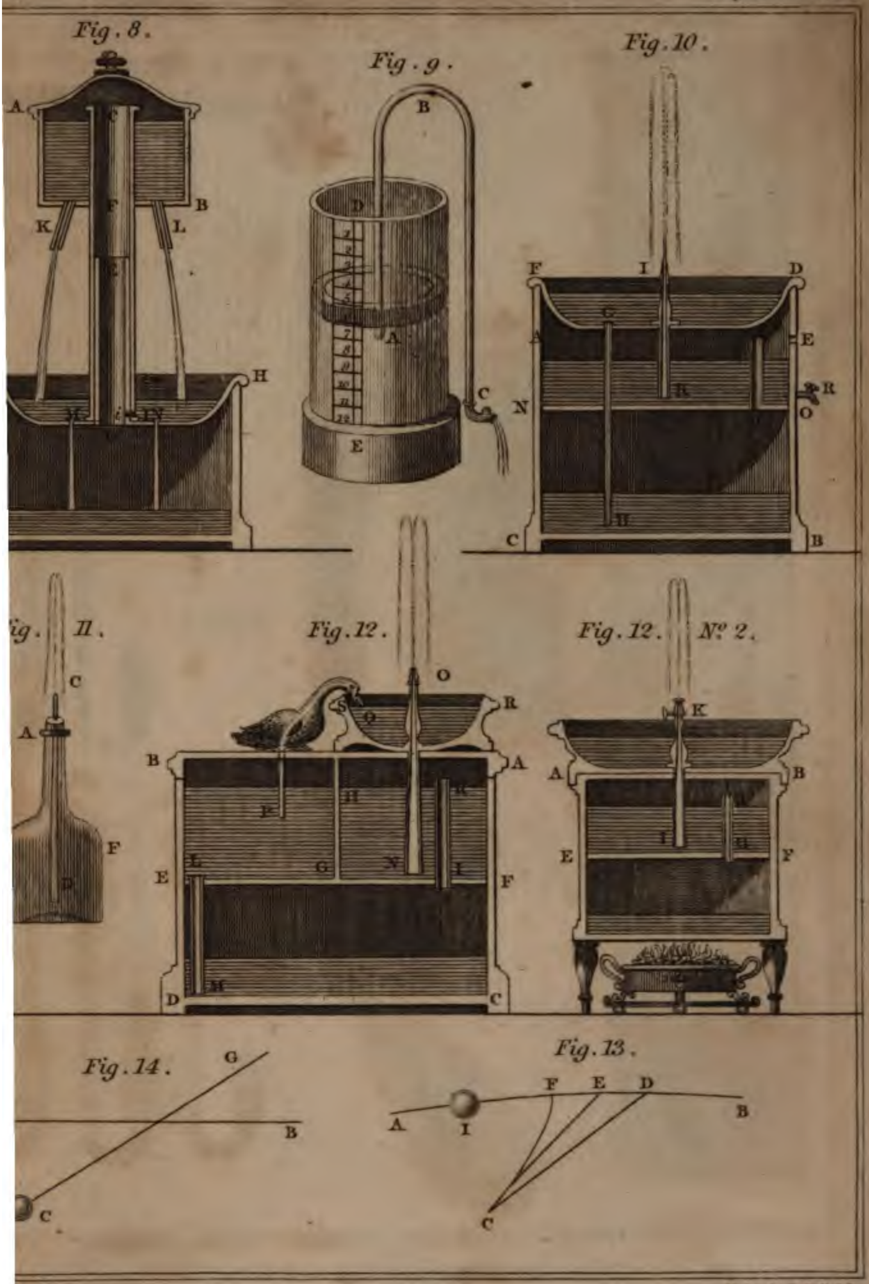

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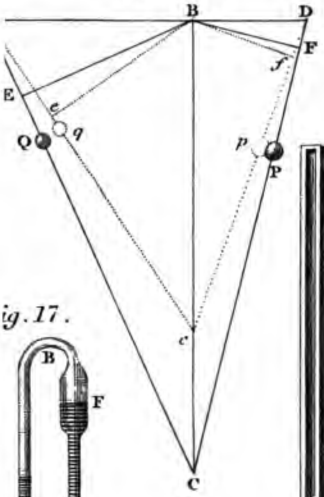

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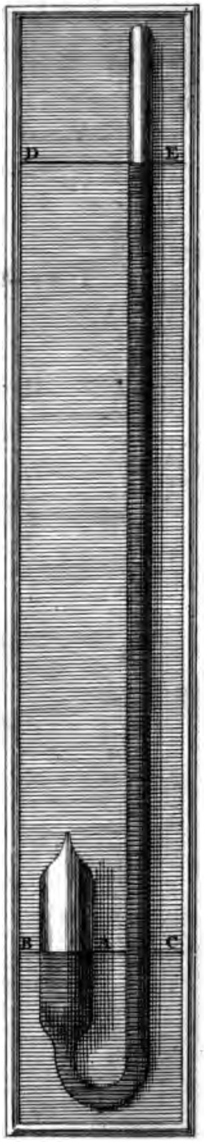

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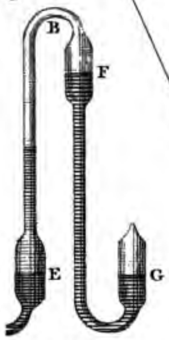

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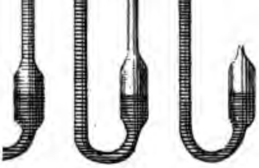

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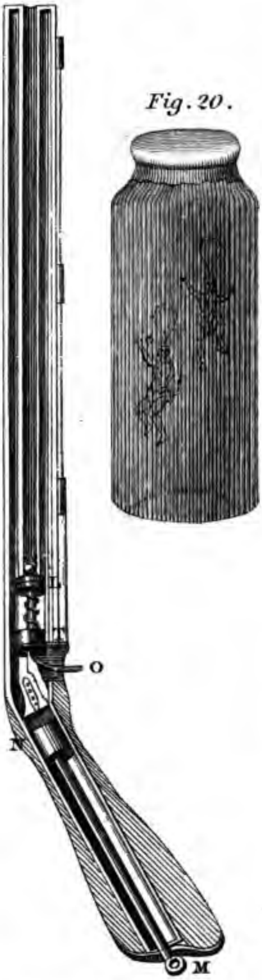

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Fig. 22.

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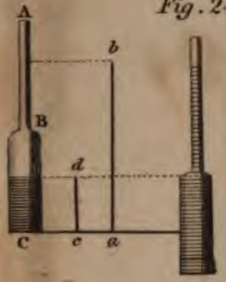

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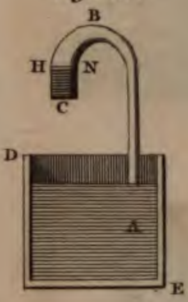

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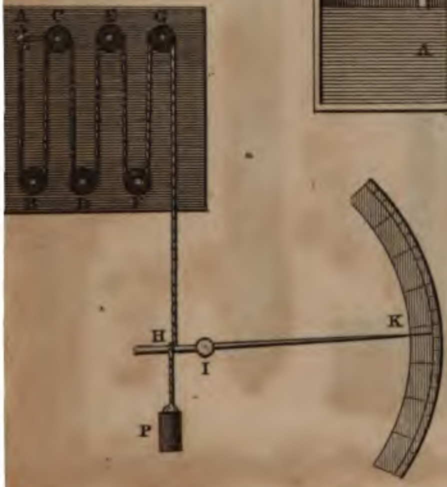

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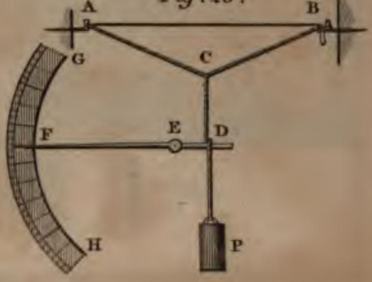

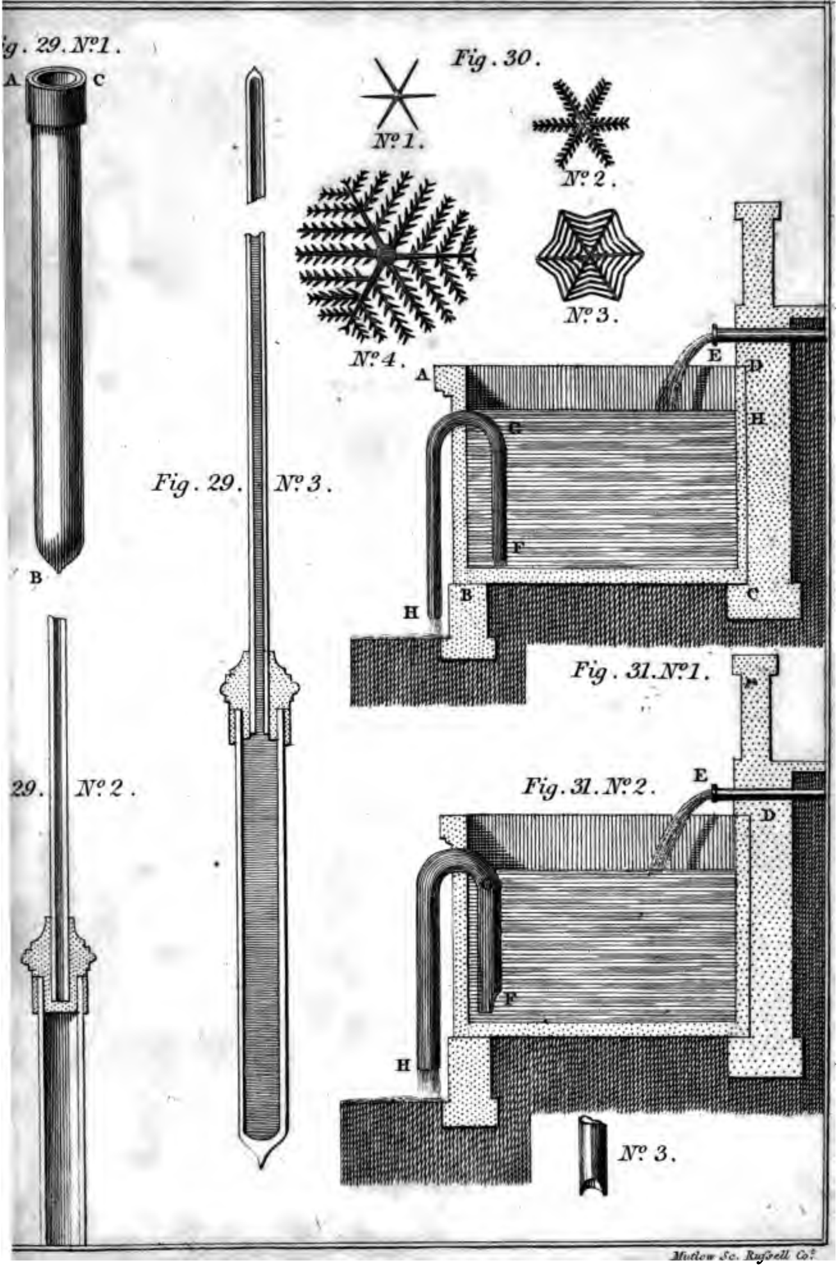

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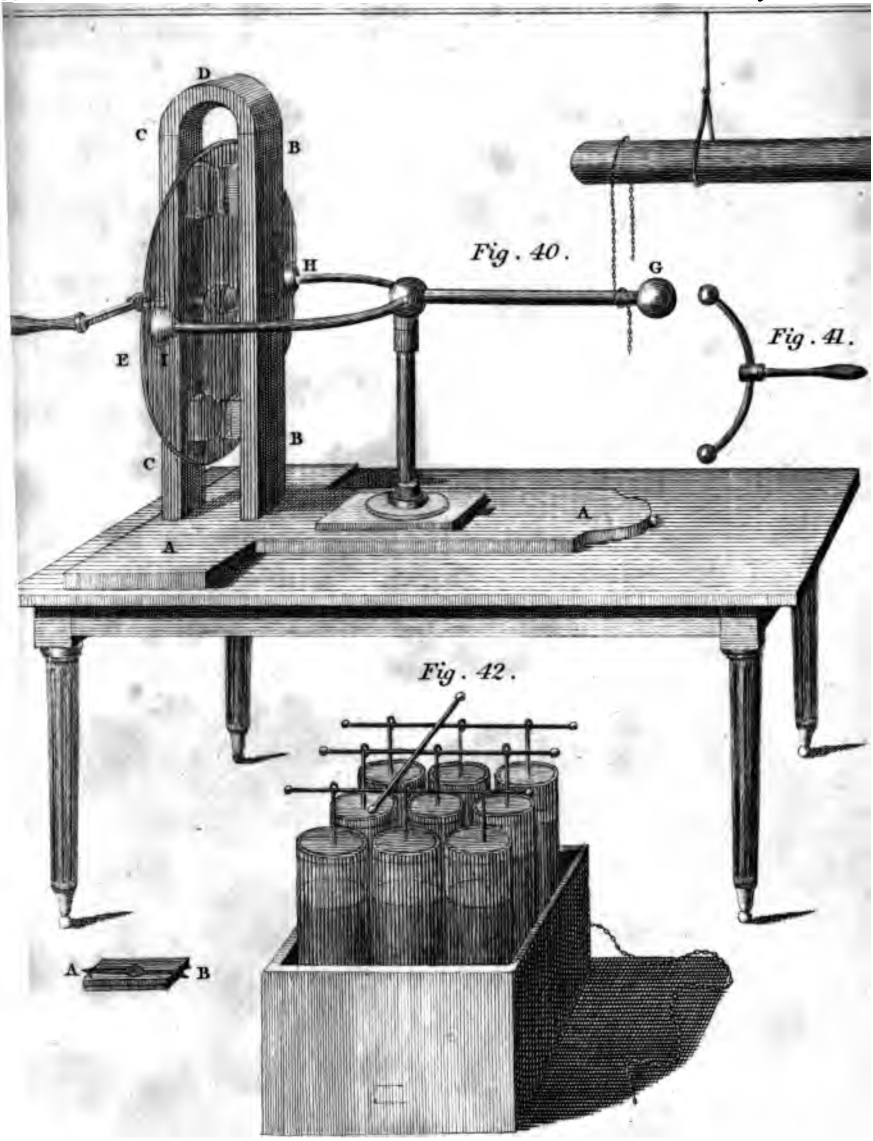


Fig. 40.

Fig. 41.

Fig. 42.

Mutlow Sc. Russell

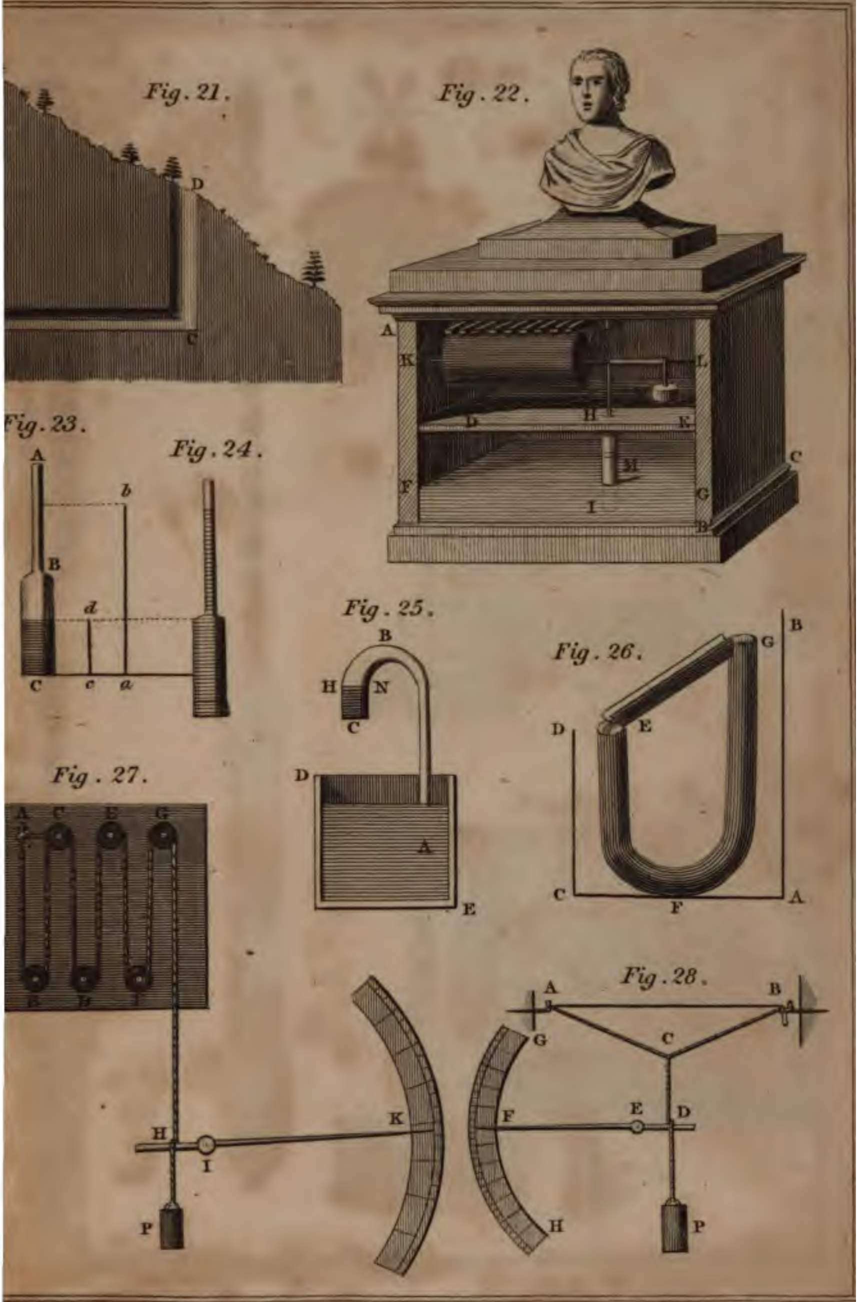
Fig. 43.

Fig. 44.

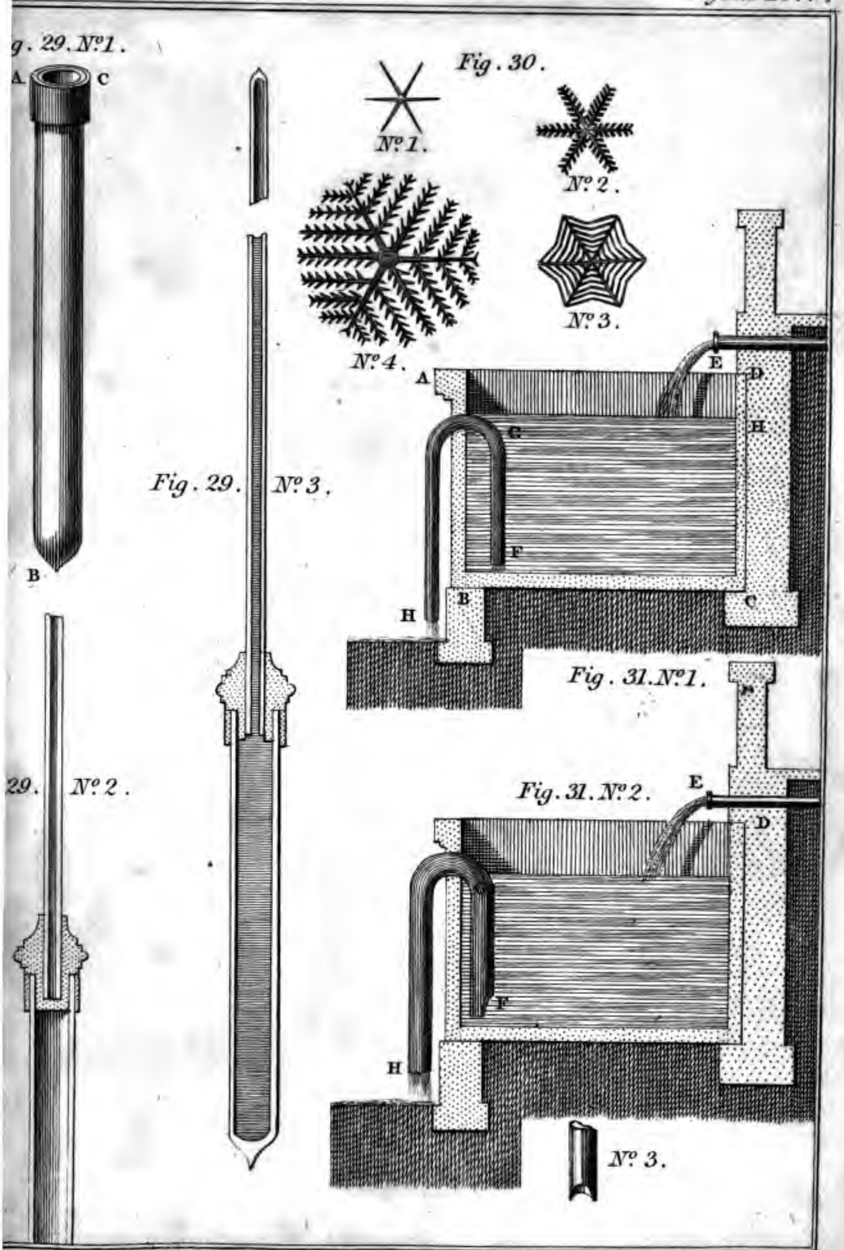
Fig. 45.

Fig. 46.

Mutlow Sc. Russell Ct.



Mutlow Sc. Russell Co.



Mutlow Sc. Russell Ct.

Fig. 32.

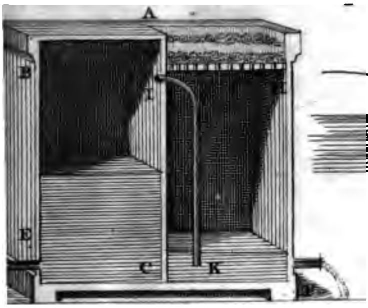


Fig. 34.

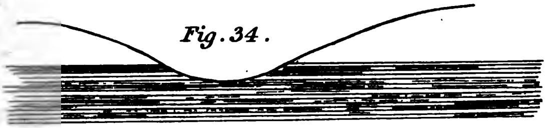
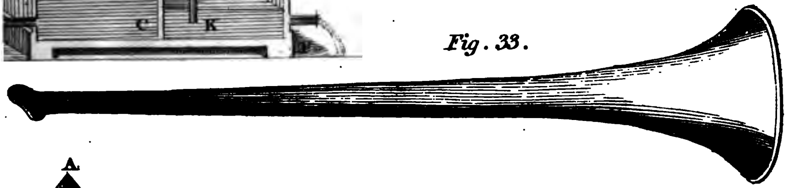


Fig. 33.



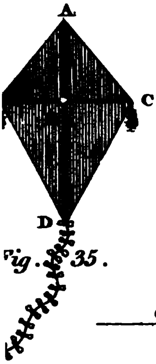


Fig. 35.

Fig. 36.

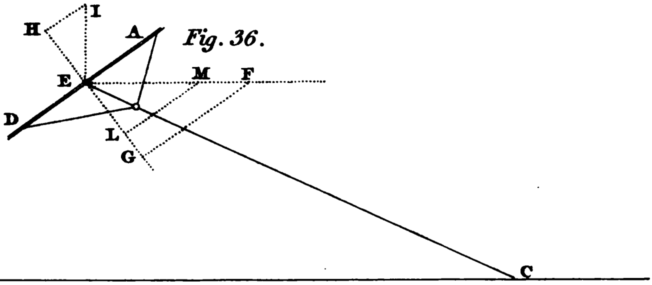


Fig. 38.

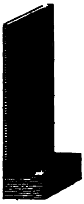


Fig. 37.

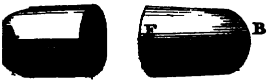


Fig. 39.

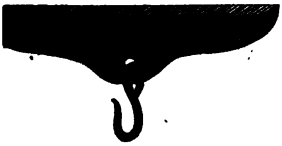
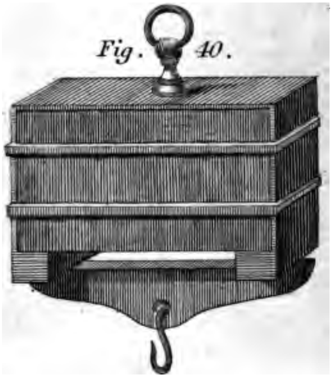
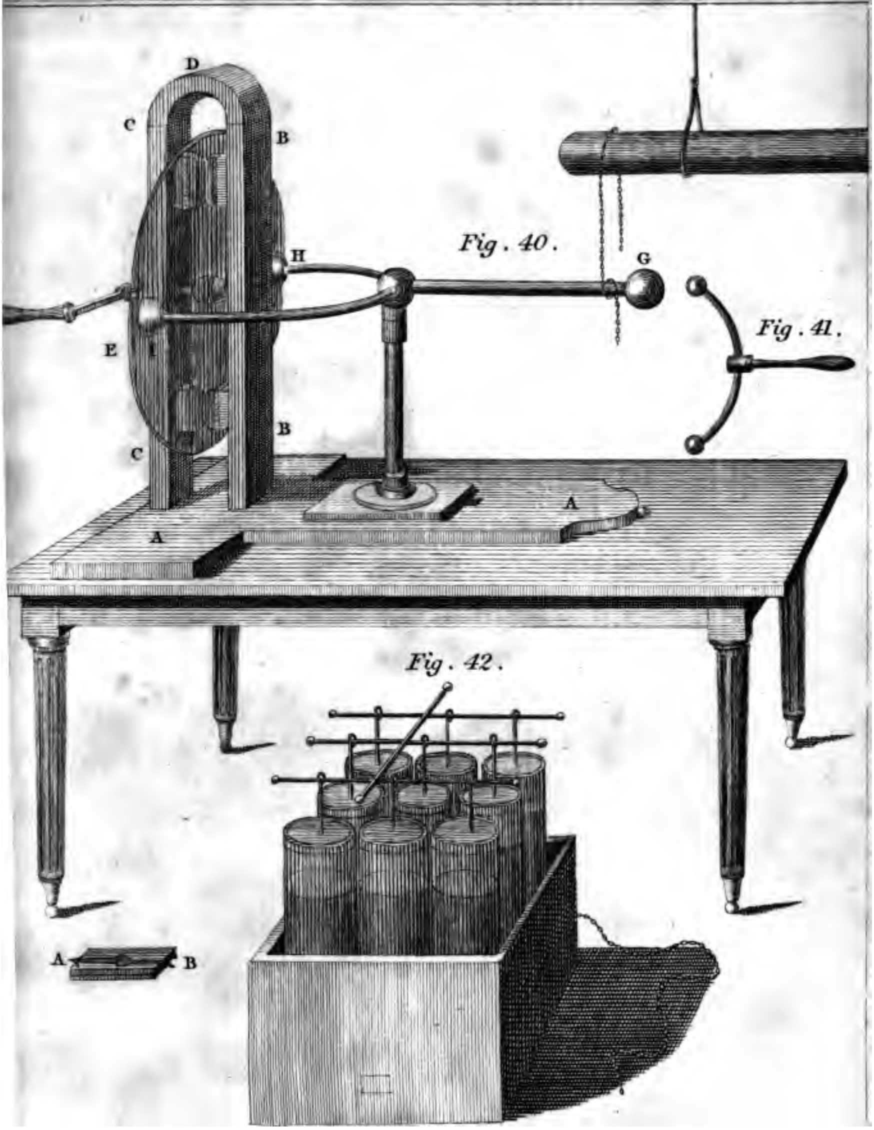


Fig. 40.





Mutlow Sc. Russell Ct.

Fig. 43.

Fig. 44.

Fig. 45.

Fig. 46.

Mutlow Sc. Russell Ct.

time, it is taken out, rubbed between the hands, opened and spread out, frequently dipping it in the water, in order to clean it from the earthy particles. This operation is repeated five or six times, until the filaments are well detached from each other, after which they are collected.

They must then be dried on some apparatus, through which the water can easily drain off. The next thing is to provide two small cards, finer than those used to card the wool employed for making hats and stuffs, and the incombustible flax must be placed between these two cards, that a few of the filaments may be drawn out at a time, in order to be spun with a small spindle.

But, it is to be observed, that as the filaments of this flax are in general very short, it is necessary to spin along with it some fine cotton or wool, which may embrace and unite them.

Care however must be taken to use always a little more amianthus than of the substance you have chosen to spin along with it. The reason of this is, that when the thread is made into cloth or into purses, the work is thrown into the fire; the cotton or wool then burns, and being consumed, nothing remains but pure amianthus. It is almost in the same manner that gold and silver is spun with silk; and that old gold or siver lace is burnt to obtain the pure metal.

Ciampini says, that those who spin this substance must moisten their fingers, and particularly the thumb and the fore finger, to render the operation easier, and to prevent the fingers from being excoriated, *because the amianthus is corrosive*. He says also that the use of cards may be dispensed with; and that it is sufficient to put the filaments of the amianthus in regular order in such a manner, that they may easily separate to insinuate themselves into the cotton or wool added, in order that they may be spun together. When the cloth or purses are dirty, they are

thrown into the fire, and on being taken out, are whiter and more brilliant than they were before. He recommends moistening them with a little oil or essence, when they come from the fire; because oil nourishes the amianthus, and causes the thread to remain smoother.

We shall here observe, that to form the amianthus into wicks, it is not necessary that it should be purified or spun. It will be sufficient to take the longest filaments, and to tie them together with a white silk thread, in a quantity proportioned to the size of the wick. It is astonishing to see with what avidity the amianthus attracts and imbibes the oil. It may be employed as it is found in filaments, in the druggists' shops, and the lamp will not fail to burn and to emit a strong light.

Ciampini however is mistaken when he ascribes to the amianthus a corrosive quality; its stony and no ways saline nature will not admit of such a property.

Having given this short history of the amianthus, it remains that we should examine the consequences that may be hence deduced.

If we can believe the partisans of perpetual lamps, since the first step towards the execution of such a work is a perpetual and incombustible wick, we have the object accomplished; for the amianthus supplies us with such a wick, since it is incombustible, and since the trials made of it have been attended with success. Father Kircher assures us, that he had a lamp with a wick of this kind, which answered exceedingly well.

We will not deny that it is possible, by means of the amianthus, to make a wick, which will last for a very long time; but we will assert that it would not be perpetual; for though the amianthus is boasted of as being incombustible, this property is not absolute. We will even venture to say, that the amianthus is at length annihilated by fire, like every other body. It is true that cloth of the

amianthus, when thrown into the fire, is taken out sound and entire, but not absolutely so. It is observed that it loses a little of its weight every time it is exposed to the fire. It would therefore be at length destroyed, and perhaps in the course of a very short time, such as a few days, if it were only made red hot and suffered to cool, or if it were left all that time in a very strong fire. Consequently a wick of amianthus would at the end of a certain period be entirely destroyed.

Some have tried to make wicks of bundles of gold threads, exceedingly fine. This perhaps would be the means of obtaining a wick almost perpetual in its duration; but it has never been possible to light them; and even if this could be done, another inconvenience would prevent their being of any use: the gold filaments would be fused by the flame, and consequently would be rendered unfit for answering the intended purpose, as it is well known, that if a piece of silver wire be presented to the flame of a taper, it is instantly fused, and the case would be the same with a gold wire, for it is more fusible than silver.

§ II. *Impossibility of procuring indestructible aliment, for the perpetual lamps. Pretended recipes for making indestructible oil.*

But we shall even suppose a wick absolutely unalterable to have been found, and that it does not become choaked up with fuliginous matter, from the combustible substance by which it is fed. This however would be only a small part of what is necessary for obtaining a perpetual lamp. Some kind of aliment, which shall experience no diminution, or which having served to maintain the flame without experiencing any alteration, may return by a perpetual circulation into the vessel from which it issued, will also be requisite. Is all this possible?

But let us now hear the alchemists, or the partisans of

perpetual lamps. We shall be entertained with their ideas respecting the manner in which an oil, such as these lamps would require, might be obtained.

Some, considering that the amianthus resists fire, have tried, but without success, to extract an oil from it.

Others, observing that gold and silver, but particularly the former of these metals, are indestructible by fire, conceived an idea of searching in them for that valuable oil which would put us in possession of perpetual lamps. This is the noble secret with which Liceti pretends that Olybius was acquainted; but the metals are as incapable of producing oil as the amianthus.

It may however be said, that if it were possible to reduce gold to a liquid state, we might perhaps obtain an incombustible oil, as gold is unalterable in the fire. But besides the impossibility of converting gold into a liquid, how do we know that it would be inflammable like oil?

The abbot Trithemius, or the person who in his name has written a great many falsehoods, pretends to give two recipes for making incombustible oil. We shall here lay one of them before our readers, with the whole process for making a perpetual lamp.

Mix, says that celebrated visionary, or the person who speaks in his name, four ounces of sulphur and four ounces of alum; sublime them, and convert them into flowers. Take two ounces and a half of these flowers, with half an ounce of borax and Venetian crystal, and pulverise the whole in a glass mortar. Put the powder into a phial, and having poured into it spirit of wine, four times rectified, cause it to digest. Pour off the spirit of wine, and having added some new, repeat the same thing three or four times, until the sulphur runs without smoke, like wax, on hot plates of brass. You must then prepare a proper wick, which may be done in the following manner: Take filaments of the asbestos stone, of the length of the finger;

even in consequence of the good colour of their matter, like that described by Philalethes and the learned Morien*, have gone so far as to purchase estates for a large sum of money. But unfortunately, every thing is still deficient, and the good alchemist dies in the hospital, protesting that nothing was wanting to his matter, but an imperceptible degree of coction, to render him the richest man on the earth.

In regard to the perpetual lamp of Naples, we shall change our opinion when we learn with certainty that it has been tried, and that it has burnt only one year.

* Two celebrated adepts.

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